Science teachers' beliefs and teaching practices in Tanzanian secondary schools

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Thesis submitted for PhD Examination

at the University of Sussex

September 2017

Declaration

I hereby declare that this thesis has not and will not be submitted in whole or part to another University for similar or any other degree award.

Signature

Acknowledgements

The completion of this thesis was the result of tremendous amount of support and cooperation of many individuals and organizations. I would like to express my gratitude to all who contributed in one way or another to make the study success. The list is extensive to acknowledge but the following deserve special attention.

- My supervisors Prof. Kwame Akyeampong and Dr. Naureen Durrani for their thoughtful guidance, patience, and encouragement throughout this study. I feel privileged to have supervisors who could genuinely uncover both the sweet and bitter tastes of my work. Indeed, they were critical friends without whom it would have been very hard to accomplish this thesis.
- Commonwealth scholarship commission in the UK for funding this study.
- University of Dar es Salaam for granting study leave and supporting fieldwork in schools.
- Teachers in the study schools for volunteering to participate in the study.
- Doctoral students and friends at Sussex for sharing ideas.
- Finally, my family, especially my wife Irasaeny for her tolerance and moral support throughout the research. Her love and constant support were crucial during hardships when my confidence and enthusiasm had declined.

Summary

UNIVERSITY OF SUSSEX

Albert Tarmo, Doctor of Philosophy

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Recent attempts to improve science teaching and learning in Tanzania required teachers to adopt a learner-centred pedagogy. Although researchers widely acknowledge a lack of sustained success in science teachers’ adoption of learner-centred pedagogy, the reasons for teachers’ reluctance to adopt learner-centred pedagogy remain debated. Various contextual constraints, including resource shortages, overcrowded classrooms, ineffective teacher education, and high-stakes exams, render learner-centred pedagogy unsuccessful. However, in the Tanzanian context, teacher educators and researchers seem to overlook the critical role science teachers’ beliefs about science knowledge, teaching, and learning play in their teaching practices. Thus, attempts to identify and address Tanzanian science teachers’ deeply held beliefs are uncommon. Therefore, I interviewed six secondary school science teachers to explore their beliefs about science knowledge, teaching and learning and to show how these forms. I also observed their lessons to examine how the teachers’ beliefs manifest in their classroom practices.

The findings showed that teachers largely espoused ‘traditional beliefs’ about science knowledge, teaching, and learning. They viewed science as a fixed body of discrete facts that mirrors natural phenomena. They believe the body of science knowledge is absolute and handed down by omniscient authorities, such as textbooks and teachers. The teachers consistently described teaching science as conveying textbook facts for students to accumulate and reproduce during exams.

Social and contextual factors, including teachers' childhood, schooling, and training experiences, as well as the bureaucratic demands, paradoxical curriculum, and students' reticence reinforced these beliefs. Teachers' beliefs, though consistent with their teaching practices, were largely antithetical to the principles and practices of learner-centred pedagogy. Therefore, I propose that Tanzanian secondary school teachers consider their beliefs and the social and contextual conditions of the schools in adopting learner-centred pedagogy. They weigh their beliefs against the social and contextual conditions to decide how to teach. These results suggest that teacher educators and policy makers should seek to transform teachers' beliefs about science knowledge, teaching, and learning through learning trajectories that require teachers to articulate and interrogate their beliefs. Such attempts should consider the social, cultural, and material contexts of the schools in which teachers teach.

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Chapter 1: Background and Rationale

1.0 Introduction

For over two decades, since the government introduced learner-centred pedagogy in secondary school science teaching in Tanzania, research still reiterates little change in the actual practices of science teachers, and attributes this to contextual constraints such as large class sizes. However, aspects internal to science teachers – their beliefs about science knowledge, teaching, and learning, which form the basis for decisions and justifications for their teaching practices – appear to receive little attention.

In this chapter, I discuss the initiatives set up to promote learner-centred pedagogy and why these appear to have made little impact in changing the core practices of secondary science teachers. Specifically, I highlight the role of science teachers' beliefs in mediating actual change in their classroom practices, and the implications of beliefs in promoting learner-centred pedagogy. I review critical links between learner-centred pedagogy and science teachers' beliefs about science knowledge, teaching and learning, and why overlooking this important relationship narrows what can be achieved in science teaching reforms, particularly in the Tanzanian context. Finally, I identify a lack of insights about science teachers' beliefs in the Tanzanian context as a key gap, which my study is aimed at addressing. In what follows, I describe my personal motivations and experiences and how these have influenced my choice of research area.

1.1 Personal motivation

Apart from the need for empirical evidence to contribute knowledge, a researcher's dispositions typically set the selection of the research agenda, which ultimately influences the research process (Savin-Baden and Major, 2013). My interest in understanding the difficulties encountered by science teachers in realising envisioned pedagogical reforms in school science teaching has largely emanated from my personal experiences as an instructor for science teaching methods courses in teacher education colleges.

Having personally experienced the way science teaching in schools is reduced to a simple process of knowledge transmission, I had aspirations for science teachers who could teach science differently. Therefore, consistent with the demands of our school curriculum in Tanzania, I have been trying, albeit with little success, to orient student teachers to the envisaged learner-centred pedagogy. I have witnessed little success by student teachers in adopting this approach despite all the efforts we have devoted to equipping them with the knowledge and skills they need. This has prompted my interest to better understand science teachers' practices in terms of how their beliefs about science knowledge, teaching and learning influence their instructional practices, and whether these are barriers to reforming their teaching practices.

1.2 Pedagogical reform: Introducing learner-centred pedagogy in Tanzania

To improve science teaching and learning in secondary schools, the government of Tanzania initiated pedagogical reform[1], which involved integrating learner-centred pedagogy into the curriculum and subsequently disseminating it through initial and in-service teacher education. Notably, efforts to promote learner-centred pedagogy began in 1996 with in-service training programmes conducted by the Ministry of Education and Faculties of Education in public universities (Osaki, 2007). However, it was not until the early 2000s that policy discourses on learner-centred pedagogy

[1] I occasionally use the term 'pedagogical reform' interchangeably with 'learner-centred pedagogy', although the former involves broader changes in teaching practices than learner-centred pedagogy.

gained more attention with the formulation and implementation of the Secondary Education Master Plan of 1998 and the Teacher Education Master Plan of 2000.

After a review of the curriculum, the Secondary Education Master Plan advocated greater emphasis on learner-centred pedagogy in science teaching and learning (Ministry of Education and Vocational Training (MoEVT), 2013). Specifically, the review stated that ‘the implementation of the current secondary school curriculum shall emphasise learner-centred pedagogy… therefore, learning shall be rooted in the conception of constructivism’ (MoEVT, 2013, p. 29). Learner-centred pedagogy was conceptualised as an approach to teaching and learning with the learner at the centre of all decisions regarding curriculum design and delivery (MoEVT, 2013). In addition, both the learner and the teacher were expected to take an active role in knowledge construction with the role of a teacher stipulated as follows:

> The teacher shall become facilitator, motivator and a promoter of learning during the classroom interactions. Teachers shall be required to plan and design relevant tasks that will let students question; *critically think; form new ideas; create artefacts and therefore bring sense in the learning process* (MoEVT, 2013, p. 29, emphasis added).

To implement this approach, teachers were urged to use interactive methods including small projects, inquiry, debates, small group discussions, laboratory work, problem solving, and presentations during science teaching and learning (MoEVT, 2013).

The government expected initial teacher education to play a central role in laying the foundation for this approach to teaching and learning. First, initial teacher education colleges reviewed their programmes to emphasise learner-centred pedagogy as an approach to teaching and learning (Osaki, 2007). The introductory section of each syllabi for science method courses emphasised the need for student teachers to develop competence in applying learner-centred pedagogy during teaching (MoEVT, 2009). An extract from a Biology pedagogy syllabus illustrates this:

> [A] student-teacher *should have the ability to apply learner-centred approaches*, strategies and techniques in the teaching and learning of Biology to learners including those with special needs (MoEVT, 2009, p. v, emphasis added).

Therefore, student teachers are required to acquaint themselves with learner-centred pedagogy as they prepare to teach science in secondary schools. This include applying learner-centred pedagogy during the 'field teaching practice' in secondary schools.

Beyond initial teacher education, there were attempts to consolidate learner-centred pedagogy through continuous professional development for practising science teachers. Some of the most popular programmes that strongly emphasised this orientation were Science Education in Secondary Schools (1996–2006), Teacher Education Assistance in Mathematics and Science (1996–2004), Science Teacher Improvement Project (1996–2003) and Education II Project (2002–2005) (Osaki, 2007). All these professional development programmes were aimed at building teachers' knowledge and skills for applying the learner-centred pedagogy (Osaki, 2007).

While policy makers including science curriculum developers have continued to see learner-centred pedagogy as a panacea to deepening learning and understanding of secondary science, a growing body of research points to challenges with sustainable adoption (Akyeampong, 2017; Barrett, 2007; Westbrook et al., 2009). Researchers have questioned learner-centred pedagogy from different perspectives.

Research shows that policy makers often conceptualise learner-centred pedagogy without sensitivity to traditional ways of learning, particularly in the African context. Tabulawa (2013), for example, argued that the learner-centred approach is incongruent with the traditional African ways of knowing. In African cultures, traditional knowledge is born of divine revelation to the privileged individuals who pass it to novices through initiation and rituals (Hamminga, 2005). African societies believe such knowledge is prefabricated, ready for use and changeable only through subsequent divine revelation, rather than through empirical scepticism and discovery as constructivists emphasise. Moreover, knowledge of culturally acceptable and shared ways of life is transmitted through storytelling, observation, imitation and repetition. In this process, the role of the novice is to watch and listen faithfully to elders who possess the knowledge.

Learner-centred principles such as questioning, scepticism, dialogue, inquiry and hypothesising are not inherent and are incompatible with traditional African epistemologies (Hamminga, 2005). In Tanzania, science teachers may be deeply inclined to local epistemologies such that they see themselves as repositories of science knowledge to transmit to students. In this case, an approach to teaching and learning that makes them co-creators or constructors of scientific knowledge may be resisted as incompatible. Indeed, a basic principle that knowledge should be co-constructed between teachers and students challenges the authority culturally vested on elders (teachers) as knowledge authorities in the African context (Tabulawa, 2013). This could strongly affect the type of pedagogy that teachers choose and the changes that they may accept.

Another perspective is that learner-centred pedagogy overemphasises learners' needs and interests without fully recognising teachers' needs and capacities

(Schweisfurth, 2015). In other words, there seems to be an undervaluing of how teachers themselves are expected to transform their beliefs to share the learning space with their students. There is also lack of recognition of the variations in contexts across which the practices of learner-centred pedagogy may not apply or may require alteration to fit the contexts (Schweisfurth, 2015).

Despite enormous efforts to disseminate learner-centred pedagogy and foster its use by science teachers, research on science teaching in Tanzanian secondary schools reiterates insignificant change in the actual practices (Semali et al., 2015; Semali and Mehta, 2012; Vavrus, 2009; Vavrus and Bartlett, 2012). Some of the most recent studies suggest that a teacher-centred pedagogy mainly involving teachers talking and writing notes on the chalkboard dominates science teaching (Hamilton et al., 2010; Mkimbili et al., 2017). Students passively listen, write notes and answer factual questions asked by the teachers to intersperse their verbal instructions (Semali and Mehta, 2012; Vavrus and Bartlett, 2012). Thus, despite the aspired change to learner-centred pedagogy in science classrooms, the default position of science teachers teaching in traditional ways persists.

Researchers have identified contextual constraints rendering pedagogical change unsuccessful, including resource-constrained large classes, high-stakes examination, overloaded curricula and demotivated ill-trained teachers (Barrett, 2007; Hardman et al., 2012; Semali and Mehta, 2012; Vavrus and Bartlett, 2012). Although the influence of contextual factors is indisputable, such research does not fully account for the persistence of traditional transmissive teaching in private schools where contextual conditions are better. This means that other factors could be equally or more important.

Beyond contextual factors, it is worthwhile to acknowledge that learner-centred pedagogy was introduced in a context in which science teachers had well-established beliefs about science knowledge, teaching, and learning. Such changes might be incongruent with teachers' deep-seated assumptions about the nature of science knowledge and how it is learned, their conceptions of learners and goal of schooling (Tabulawa, 2013). Thus, changes in science teachers' practices inevitably require teachers to reconstruct their deeply held beliefs. In the next section, I discuss the links between teachers' beliefs and their classroom practices.

1.3 Science teachers' beliefs and their teaching practices

The foregoing section brings to the fore the fact that initiatives set up to promote learner-centred pedagogy were preoccupied with equipping science teachers with knowledge and skills for the aspired pedagogy. However, the role played by well-established beliefs and values in the implementation of reform initiatives has received little attention. Overlooking the influence of teachers' beliefs about science knowledge, teaching and learning on their classroom practices might have compromised the reform initiatives, thereby narrowing the chances of successful change.

The processes through which teacher candidates were socialised into 'becoming' science teachers could have left strong imprints on their assumptions about science knowledge and how it is acquired; thus, they resist attempts to dislodge these deeply rooted beliefs. Beliefs are known to be resistant to change and reflect the actual nature of teaching practices (Fang, 1996; Kagan, 1992). Research shows that science teachers' beliefs act as a mental screen through which new knowledge, including teaching reform recommendations, are filtered (Pajares, 1992; Thomas et al., 2001). Science teachers' subjective understandings influence every aspect of their practice. These often serve as the basis for instructional decisions and justifications (Fives and Buehl, 2016; Park et al., 2010; Yerrick et al., 1997). In short, beliefs mediate most aspects of teacher practices, including the kind of science teachers they aspire to become (Mansour, 2009).

Teacher candidates hold beliefs about the teaching profession because of the many hours they spend observing teachers (Lortie, 2002). They hold vivid images of science teaching from their schooling experiences. These affect their interpretation of teacher education courses and powerfully influence the knowledge and projected practices they might later apply as teachers (Levin and Ye He, 2008). This is because when teachers are presented with new teaching approaches, often they are likely to accept approaches congruent with their beliefs, but will be sceptical or resistant to alien ones (Wallace, 2014). Therefore, prior beliefs about good science teaching and learning formed through schooling experiences may be a formidable force in shaping future teachers and how they respond to pedagogical reforms (Luehmann, 2007).

In the Tanzanian context, little is known about how science teachers might have developed this ‘shield’ and how it is manifested in their instructional practices. There is also lack of understanding about how science teachers might reconceptualise learner-centred pedagogy in ways that can act as a catalyst to work with their students through more collaborative spaces to co-construct and interrogate science knowledge. Further, prospective science teachers might have had less experience of learner-centred teaching during their schooling. Therefore, many may perceive themselves to be successful science learners in traditional classrooms dominated by teacher-centred pedagogy; hence, they could struggle ‘internally’ with the tenets of the aspired learner-centred pedagogy. Thus, to prepare science teachers who can enact learner-centred pedagogy, it is important to explore their prior beliefs about science knowledge, teaching and learning that might have played a large role in shaping their practices and how they themselves learn and enact new practices (Avraamidou, 2014a; Luehmann, 2007).

Preparing science teachers who can implement reforms goes beyond acquiring a new set of knowledge and skills offered during teacher education (Luehmann, 2007). Crucially, it requires forming and reforming oneself as a science teacher through experiences that will reconstruct one's pre-existing beliefs (Avraamidou, 2014a; Danielsson and Warwick, 2014). In the Tanzanian context, it is important to understand the extent to which teachers' pre-existing beliefs may be amenable to reconstruction, to reflect reformers' notions of learner-centred pedagogy. It is also important to understand how teachers have adapted learner-centred pedagogy consistent with their existing beliefs about science knowledge, teaching and learning.

Concerning practising science teachers, I argue that apart from the beliefs they hold because of their own schooling experiences, these teachers may have well-established science teaching practices and values. These may differ from learner-centred teaching practices advocated in in-service training programmes and science curricula. Often, science teachers hold experiences, beliefs, knowledge and values pertaining to science teaching that are very different or even contradictory to those that teaching reformers and policy makers advocate (Luehmann, 2007). In the Tanzanian context, it is important to understand how well-established science teaching practices mediate learner-centred pedagogy advocated through in-service training programmes.

To summarise, prior beliefs about what constitutes good science teaching play a critical role in the acquisition and understanding of new knowledge and subsequent teaching practices of science teachers (Kagan, 1992; Pajares, 1992). Thus, the continuation of antiquated and ineffectual teaching practices could be deeply rooted in unexplored and unreconstructed prior beliefs held by science teachers. These could be contradicting the acquisition and application of teaching practices that reflect reformers' model of learner-centred pedagogy (Pajares, 1992; Thomas et al., 2001). Considering the background details provided, this study aimed to explore science teachers' beliefs about science knowledge, teaching and learning, and how these are manifested in their teaching practices in the context of secondary education in Tanzania. Specifically, I addressed four research questions.

1.4 Research questions

1. What beliefs about science knowledge, teaching and learning do science teachers hold in Tanzania?

2. How do science teachers develop their beliefs about science knowledge, teaching and learning in the Tanzanian secondary education context?

3. How do science teachers' beliefs relate to their teaching practices?

4. What explains the nature of science teachers' teaching practices?

1.5 Thesis overview

Chapter 1 outlines the initiatives setup to improve secondary science teaching through learner-centred pedagogy and highlights lack of success in reforming the core practices of science teachers. It identifies teacher beliefs as one of the key factors that might be constraining teachers from adopting learner-centred pedagogy. Chapter 2 locates the study in the geographical and social context of Tanzania. It covers background information about education system and draws attention to the literature on the state of science teaching and learning in secondary schools.

Chapter 3 outlines the conceptualisations of the key construct 'teacher beliefs' and 'pedagogy'. It presents literature on the nature, and formation of teachers' beliefs. The chapter outlines relevant beliefs in the context of teaching reforms by drawing on the theory of an epistemological belief system (Schommer, 1990) and categories beliefs about teaching and learning (Kember, 1997; Marton et al., 1993). Chapter 4 describes a phenomenological approach to researching teacher beliefs locating this within the broader interpretivist ontology and epistemology. It covers descriptions of the selected research schools and teachers and the methods I used to collect and analyse data.

Chapter 5 presents thematic categories of beliefs about science knowledge, teaching and learning uniformly held by all or some of the six participants. Chapter 6 presents social, and contextual conditions shaping science teachers' beliefs. Chapter 7 analyses science teachers' practices focusing on the specific elements of the lesson. Chapter 8 discusses the relationship between science teachers' beliefs and their teaching practices. It maps out the consistencies and inconsistencies between teachers' beliefs and practices to demonstrate how beliefs manifested in different aspects of the lessons. It discusses how teachers' beliefs contradicts the principles and practices of learner-centred pedagogy stipulated in the current secondary science curriculum in Tanzania.

Chapter 2: Context

2.0 Introduction

This chapter provides general information about Tanzania. It covers the context of secondary education particularly ordinary level secondary education, which is the focus. Further, using the relevant literature, I describe the condition of science teaching and learning in Tanzania and factors constraining the reform efforts.

2.1 About Tanzania

The United Republic of Tanzania is a union of two sovereign states of Tanganyika and Zanzibar. Tanzania is in East Africa and has an area of 945,000 km^2 divided into 30 regions of which Dodoma is a capital and Dar es Salaam is a major commercial city. According to the Tanzania National Bureau of Statistics (NBS), there were over 50 million people in 2016, over 70% them live in rural areas.

In 2017, the Prime Minister's Office-Regional Administration and Local Governments (PMO-RALG) estimate around 9 million pupils aged 6-13 years are enrolled in primary schools in Tanzania (PMO-RALG, 2014). Among them 96.3% are attending government schools and 3.7% are attending non-government schools. Likewise, around 2 million students aged 13-18 years are enrolled in secondary schools. Of these 81.9% are attending community and government schools while 18.1% are attending non-government schools.

Tanzania is a developing country. Agriculture, tourism, fishing, forestry, mining, and trade are the major economic activities. Low levels of science and technology and shortage of human resource limits the growth of manufacturing sector. This makes investment in human capital development through science and technology education critical for the country's development (Osaki, 2007).

2.2 Education system in Tanzania

Ministry of Education and Vocational Training in collaboration with the Ministry of Regional Administration and Local Governments provide education in Tanzania (MoEVT, 2014). Local communities, religious organizations and individuals also contribute significantly. The education system constitutes formal, non-formal, vocational and professional education sub-systems. This study focused on formal education.

2.2.1 Formal education system

Formal education is predominantly academic ranging from pre-primary to University. It consists of basic, secondary and tertiary education. The structure of the formal education system is 1:6:4:2:3+ (see figure 2.1). This consists of one year of pre-primary, six years of primary, four years of ordinary level secondary education, two years of advanced level secondary education and three or more years of undergraduate university education (MoEVT, 2014). Recent education and training policy of 2014 recognises pre-primary, primary and ordinary level secondary education as a basic and compulsory education (MoEVT, 2014).

Unlike the previous, the 2014 education policy recognises both Kiswahili and English as languages of instructions throughout the education system though English is emphasised from ordinary level secondary education onwards. This study focused on ordinary level secondary education (o-level), which I describe next.

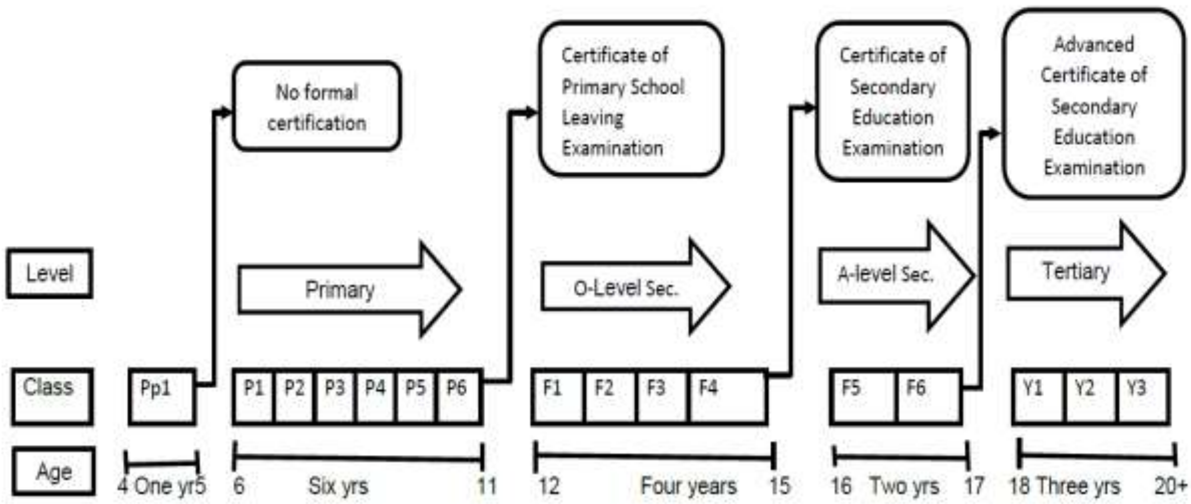


Fig.2.1: Formal Education System in Tanzania (Pp=pre-primary, P=Primary, F=Form, Y=Year).

2.2.2 O-level secondary education

This consists of four years. Performance in the Primary School Leaving Examination (PSLE) administered at the end of the sixth year serves as criteria for enrolment into o-level secondary education (MoEVT, 2014). At the end of the second-year of secondary education, students sit for the Form Two National Examination (FTNE) in which an average score of 30% is required to progress with the rest of the two years. At the end of the fourth-year, students sit for the Certificate of Secondary Education Examination (CSEE), which determines one's progression to advanced level secondary education (MoEVT, 2014).

Considering the ownership, secondary schools in Tanzania can be categorised into government, private and community schools. The proportion of schools by ownership is 75.2% community, 22.9% private and 1.9% government schools (PMO-RALG, 2014). Thus, community schools form the largest proportion of all secondary schools in Tanzania. These are day schools established by the local communities to expand access. Often the local community set up the basic infrastructures such as classrooms, desks and teachers' houses while the central government recruit teachers and supply basic teaching materials including textbooks.

Unlike the community schools, the government schools are mainly government funded highly selective boarding schools. Parents contribute tuition fee especially for advance level secondary education. Private schools are either owned by individuals, religious and non-religious organisations. Most of these are for profit, therefore they charge tuition fee to cover the financial requirements for running a school.

2.2.3 O-level secondary education curriculum

This section describes the principles and assumptions about knowledge, teaching and learning that underlie the secondary education curriculum in Tanzania. Such principles and assumptions shape the discussion in section 8.3. The curriculum in this context refers to the general curriculum document for all subjects (MoEVT, 2013) and the syllabi for Biology, Chemistry, and Physics.

The secondary education curriculum was revised to improve its relevance and delivery following the Secondary Education Master Plan of 2000. This was to respond to concerns that the curriculum was ‘irrelevant to the current demands of the society [and] the delivery system is poor’ (MoEC, 2000, p. 17). The curriculum revision involved ‘[a] change in paradigm from that of content-based to a competence-based curriculum’ (MoEVT, 2017, p. iii) to improve ‘relevance’ and to make it ‘more responsive to the changing labour market conditions’ (MoEC, 2000, p.17). A market responsive curriculum equips learners with employable skills including critical and creative thinking, communication, numeracy, independent learning, interpersonal and technology literacy (MoEVT, 2013). It produces graduates capable of generating knowledge, thinking creatively, and solving complex socio-economic problems facing society.

To achieve its principal aim, the revised curriculum emphasises holistic learning, application of subject knowledge, and higher order skills (MoEVT, 2013). It states that teachers should ‘promote the acquisition and appropriate use of scientific… and other forms of knowledge’ (MoEVT, 2013, p. 12). Intrinsic to the objectives of the revised curriculum is the notion of knowledge ‘acquisition’ or the need to ‘gather knowledge… from diverse subjects’ which indicates a conception of knowledge as an entity located in the external realm prior to learners’ engagement with it (MoEVT, 2013, p. 17).

Subject knowledge is structured into five key learning areas, which are Languages, Natural Science and Technology, Social Science, Business, and Aesthetics. Schools differ in the number of subjects they offer, depending on whether they specialise in science, social science, or business studies. The core subjects are Mathematics, Kiswahili, English, Biology, Civics, Geography, and History. Students in science streams study Chemistry and Physics, while those in business streams study Commerce and Bookkeeping as optional subjects. This strong framing of the curriculum into separate disciplines, with emphasis on the symbolic boundaries between subject streams appears to contradict the promotion of holistic learning (Bernstein, 2000). Not only is the curriculum organised into separate subjects; but the lessons, activities and tasks are strongly structured in terms of time and pace of delivery (Bernstein, 2000). The curriculum states that ‘a week of teaching shall have a minimum of 40 periods and each period have duration of 40 minutes. The daily total instructional time shall be 5:20 hours’ (MoEVT, 2013, p. 17). This statement signifies knowledge fragmentation and assumes standard learning among diverse learners.

Beyond knowledge acquisition, the curriculum demands that teachers promote students' 'intuitive and imaginative thinking ability to evaluate [scientific] ideas, processes, and experiences in meaningful contexts' (MoEVT, 2013, p. 14). It goes on to state that teachers should encourage 'critical and creative thinking to generate [scientific] ideas, processes, […] and objects by students' (p. 14). Furthermore, it emphasises that teachers should encourage students 'to understand how knowledge is created, evaluated, refined and change… [and] access wider sources of knowledge' (p. 15). In science teaching, such principles imply that teachers should encourage students to understand the nature, structure and processes through which scientific knowledge progresses. Facilitating students' understanding of 'how scientific knowledge is created' suggests that the curriculum needs teachers to facilitate students' ability to appreciate and model imaginations, inventions, and creativity which are inherently part of how scientific knowledge progresses.

To improve delivery, learner-centred pedagogy was adopted with the assumption that the intended competencies to be developed by students are not products that can be transferred from a teacher to the learner; rather, they are outcomes of learning activities that learners perform either individually or collaboratively. The curriculum therefore explicitly refers to principles of constructivism that underlie learner-centred pedagogy. Notably, the curriculum stipulates that:

> learning shall be rooted in the conception of constructivism where the student gets opportunities to interact with environment through well-organised tasks, dialogue and reflections on learners' conceptions and eventually arriving at agreed solutions through use of various senses (MoEVT, 2013, p. 29).

The curriculum further emphasises that teachers should promote the

> development of self-confidence, inquiry minds, […], desire and interest for life-long learning and personal growth' with the aim of having learners 'take responsibility of their own learning… and make responsible decisions and take actions in dealing with their own learning' (MoEVT, 2013, pp. 12 & 15).

The curriculum envisages that teachers 'promote the acquisition and appropriate use of … scientific skills and attitudes…' by providing opportunities for students to model scientific inquiry (MoEVT, 2017, p. iii). To achieve this goal teachers are 'required to plan and design relevant tasks that will let students question, critically think; form new ideas; create artefacts…' (MoEVT, 2013, p. 29). The aim is to 'bring sense [to the] learning process' (p. 29) by encouraging students to 'think reflectively and logically … for themselves, recognise[ing] the limits of individual reflections and the need to contribute to and build upon mutual understanding' (p. 14).

Overall, such a curriculum calls for teachers to adopt a constructivist-based learner-centred pedagogy. The policy requires teachers to place students at the centre of the teaching and learning process, engaging them actively in selecting the content and setting the sequence and pace of learning (Bernstein, 2000). The curriculum stipulates that 'the learner shall be placed at the focus of all the decisions that are made about the curriculum and how it will be delivered' (MoEVT, 2013, p. 29). In practice, this involves helping students to set learning goals, exploring their prior knowledge, and guiding them through collaborative activities to construct knowledge from the subject matter and their experiences. Learning in such classrooms is characterised by active interaction, reflection and negotiation of meaning, the aim being to promote holistic understanding and to develop a wide range of skills, including problem solving, critical thinking, an enquiring mind and self-confidence.

The curriculum requires teachers to employ both summative and formative assessment strategies such as 'assignments, tests, projects, and terminal examinations' to assess wide range of competencies (MoEVT, 2013, p. 30). Two official national examinations are conducted at Forms II and IV. Form II national examination scores determine progress to Form III, and Form IV national examination scores are used for selection to further education, training and work (MoEVT, 2013).

Research reports mismatch between policy prescriptions and practices on the use of formative assessment (Semali and Mehta, 2012; Vavrus and Bartlett, 2013). The system is high-stake, mainly relying on paper and pencil tests comprising objective questions, which measure textbook knowledge recall (Vavrus and Bartlett, 2013). Even the science practical work often emphasises recall of factual information presented in laboratory manuals (Mkimbili et al., 2017). Although objective items are preferred because of standardised grading, such items often seek single fixed answers and are therefore likely to promote narrow conception of subject knowledge.

Teachers often struggle to deliver the competence-based curriculum through learner-centred pedagogies because the high-stake exam context reinforces teaching how to recall textbook facts. Knowing that the high-stake exams measure recall of decontextualized textbook facts, teachers often prefer pedagogies that promote memorisation rather critical thinking and deeper understanding (Vavrus and Bartlett, 2013). Furthermore, because teachers often receive financial rewards when students score highly, and in some schools their tenure depends on pass rates, this high-stakes system motivates teachers to teach to the test, thereby discouraging the adoption of learner-centred pedagogy, as described next.

2.3 Science teaching and learning in secondary schools

Although learner-centred pedagogy was introduced in conjunction with teacher professional development, research on secondary school science teaching indicates the persistence of teacher-centred pedagogy. Teachers have tenaciously continued to teach using expository methods including lecture, recitation and closed questions seeking choral answers (Barrett, 2007; Hardman et al., 2015, 2012; Roberts, 2015; Semali et al., 2015; Semali and Mehta, 2012; Vavrus, 2009; Vavrus and Bartlett, 2012).

While science curriculum requires teachers to adopt learner-centred methods, most teachers largely employ teacher-centred methods including lectures and recitation techniques (Hamilton et al., 2010). Passive listening to teacher-led verbal instruction interspersed with writing notes on the chalkboard for students to copy characterises teaching (Semali and Mehta, 2012; Vavrus and Bartlett, 2012). Occasionally, teachers interspersed lecturing with closed verbal questions that elicited recall of textbook facts (Hardman et al., 2012; Semali et al., 2015).

Teachers often served as the learners' only source of knowledge making teacher-talk and delivery of knowledge inevitable (Hamilton et al., 2010). They tailored teaching to answering past examination questions through drilling students to memorise mandated textbook content. This is crucial for answering examination questions, which often test recall of textbook knowledge. In short, content knowledge is considered a standard of learning (Semali and Mehta, 2012).

Researching teachers who participated in in-service training on learner-centred pedagogy, Vavrus and Bartlett (2012) found that although teachers engaged students verbally than in a traditional lecture style, they regularly asked factual questions for which they sought single answers. Notably, aspects of learner-centred teaching such as co-construction of knowledge between teacher and students and classroom questioning that encourage divergent thinking rarely featured in teachers' practices. Collectively these studies demonstrate that despite efforts to review school curriculum and train science teachers, habitual ways of teaching continue to persist. This substantiates that teachers have recidivated to the traditional teacher-centred talk and chalk approaches for teaching science despite enormous efforts and resources channelled at promoting pedagogical change.

Indeed, classroom research in other sub-Saharan African countries reiterates a lack of sustained success in the adoption of learner-centred pedagogy (Akyeampong, 2017; Guthrie, 2016; Mtika and Gates, 2010; Schweisfurth, 2011). Therefore, rote and recitation approaches to teaching and learning continues to dominate in sub-Saharan African classrooms, including in the Tanzanian context (Hardman, 2015). While researchers agree that the envisaged paradigm shift in teaching from the dominant teacher-centred approaches to learner-centred pedagogy remains unrealised, the reasons for this state of affair are disputed (Guthrie, 2016). Various constraints rendering learner-centred pedagogy unsuccessful have been identified as discussed next.

2.4 Constraints to the adoption of learner-centred pedagogy

Research recognises contextual constraints as part of the reasons for the failure to change science teachers' pedagogical practices (Semali and Mehta, 2012; Vavrus and Bartlett, 2012). These include teacher-related attributes such as low motivation, weak academic credentials, and poor teaching skills.

Semali and Mehta (2012) for example observed that teachers were not enthusiastic to teach science because they felt those teaching sciences receive unfair compensation relative to the effort and time they invest in preparing laboratory activities. Because the government accord low status to the teaching profession, teachers are demotivated and constrained by poor working and living condition, low pay and rare opportunities for promotion. The pedagogical implication of enrolling under-qualified demotivated teachers is that they are less committed to improving their professional practices (Vavrus and Bartlett, 2012).

Large-resource constrained classrooms also militate against the effort to improve teaching through interactive methods (Semali and Mehta, 2012; Vavrus and Bartlett, 2012). In Tanzania, school laboratories-a valuable resource for teaching through inquiry often lacked basic supplies and in some schools, there are no laboratories at all (Semali and Mehta, 2012). Consequently, teachers largely conduct experiments to prepare students for practical examinations (Mkimbili et al., 2017). Further, because of overcrowding, more than ten students often share a single book in some schools. Large class sizes made it difficult for all students to participate in practical work forcing some to simply watch others perform experiments.

While contextual conditions may constrain learner-centred teaching in some schools, such explanation is inadequate for the well-resourced private schools. Even in such schools, science teaching is predominantly teacher-centred with inquiry learning being narrowed to recipe-type experiments where students followed prescriptive procedures to verify known scientific facts (Mkimbili et al., 2017; Vavrus and Bartlett, 2012). Further, even in the resource-constrained schools, opportunities for inquiry based science teaching using locally available materials and specific questioning techniques that connects textbook knowledge to local science applications remain untapped (Mkimbili et al., 2017). This points to the need for deeper explanations which this study sought to offer.

Other barriers to learner-centred pedagogy include content overloaded curriculum and high-stake examination (Hamilton et al., 2010; Mkimbili et al., 2017). Shortage of time and pressure to cover mandated syllabus constrained teachers from adopting learner-centred pedagogy. Teachers find learner-centred pedagogy time demanding than conventional lecturing which they find effective at delivering the mandated content (Vavrus and Bartlett, 2012). Further, high-stake national examination, which mainly measures recall of textbook content promotes transmissive teaching methods which teachers find effective for drilling students to memorise tested facts (Vavrus and Bartlett, 2012). Practical examination and manuals also powerfully influences the kind of investigative tasks teachers assigned students. Teachers often use questions from previous practical examinations to drill students on what they believed will be assessed in the practical examination (Mkimbili et al., 2017).

Recently, the language of instruction policy, which emphasises the use of English in teaching secondary education students whose proficiency levels are low, was found to impede active classroom interactions (Barrett and Bainton, 2016). Researchers observed that such policies create a multilingual and a multimodal learning environment which demands multiple transitions and movements between informal talk using local language (Kiswahili) and formal talk in English. Learning in such contexts demands that teachers support students by defining specialised subject vocabularies and giving direct translation of key concepts in Kiswahili using transmissive pedagogic strategies.

This position, however, suggests that if language of instruction is changed to Kiswahili, students will actively interact during the lesson, which translates into successful learner-centred pedagogy. Research in primary classrooms where the language of instruction is Kiswahili contradicts the view that it is lack of language proficiency that constrains active students' participation and the adoption of learner-centred pedagogy (Hardman et al., 2012). In Southern Tanzania, Roberts (2015) found that many primary students were reluctant to speak and take active roles in classroom discussions even though Kiswahili was the language of instruction. This points to the need for deeper explanations about what might be core to students' reluctance to active participation in learner-centred teaching environment apart from language proficiency. Therefore, beyond the language of instruction policy, I focused on deeper cultural beliefs and how these might impede classroom interactions.

In summary, researchers recognise classroom social and contextual conditions for constraining the adoption of learner-centred pedagogy in Tanzania. Consequently, the government and the stakeholders have directed massive resources to improve classroom conditions, teacher education and professional development. Yet, the default position of teachers teaching in transmissive ways remains widely acknowledged (Mkimbili et al., 2017; Semali and Mehta, 2012; Vavrus and Bartlett, 2012).

From my professional and contextual experiences, understanding why teachers and student teachers were quick to discard the learner-centred pedagogic practices that they learn during teacher education in favour of traditional transmissive teaching was a puzzle. At Songea Teachers' College and later the University of Dar es Salaam – where I taught science method courses for Diplomas and Bachelors in secondary science education - we devoted effort at equipping students' teachers with knowledge and skills on learner-centred methods following the teacher education curriculum. It was mystifying to realise that when we sent student teachers to schools during the field teaching practice, they often taught contrary to the learner-centred methods they learned during college-based training. This was puzzling given that some field teaching practice schools were less resource-constrained private schools with class sizes far smaller than the standards. Further, student teachers were less subject to bureaucratic ‘pressures’ for covering the syllabus and passing students because they were teaching for a brief period. This means such social and contextual barriers could not fully account for the lack of sustained adoption of learner-centred pedagogy, and, therefore, removing such barriers may not translate into improved pedagogic practices.

As a science methods course instructor, I acknowledge that our teacher education did not engage with prior beliefs that teachers and teacher candidates bring with them when they join teacher education programmes. We introduced teacher candidates to innovative ideas about learner-centred methods without identifying the pre-existing beliefs they held about knowledge and how it should be taught. Coincidentally, the contextual literature discussed in this section shows that well-established beliefs about what constitute knowledge and how teachers should teach and students should learn appears to have received little research and policy attention in the Tanzania context.

Well-established beliefs that teachers and teacher candidates bring into teacher education and teaching, forms a crucial but largely overlooked aspect that might have constrained what teacher change intervention could achieve in terms of pedagogical change. Teachers for example, may hold beliefs about knowledge, teaching and learning that are at odds with the principles underlying learner-centred pedagogy (Koballa et al., 2005). Further, while learner-centred pedagogy is founded on particular assumptions about knowledge, teaching and learning (Guthrie, 2016), its implementation in the classroom inevitably involves teachers and learners who possess their own deeply held beliefs shaped by their cultural and educational backgrounds (Fives and Buehl, 2016). Whether the two 'sets' of beliefs are congruous and what happens when these are incompatible is the subject that has not been critically examined in Tanzania. Attempts to identify teacher beliefs are scarce thus; interventions to bring pedagogical change suffer from little engagement with transforming teachers' beliefs that underlie their practices. This study aimed to fill this gap by exploring teachers' beliefs in Tanzania thereby illuminating on how beliefs might have militated against the attempts to improve teaching through learner-centred approaches in the context of secondary science. In what follows, I reviewed literature on science teacher beliefs.

Chapter 3: Literature Review

3.0 Introduction

In this chapter, I present literature on teacher beliefs showing how 'beliefs' and 'teacher beliefs' are conceptualised. Afterward, I describe factors forming and shaping teachers' beliefs. I identify beliefs relevant to teaching reforms and how these relates with the actual pedagogical practices of science teachers. Lastly, I explore how teaching practices are conceptualised with specific focus on the conceptual and analytic frameworks I used to analyse teaching.

3.1 Science teacher beliefs: Meaning

Research exploring the ideas, assumptions and thoughts that underlie teachers' classroom practice uses various terms including personal theories, personal knowledge, practical knowledge, mental images, views, conceptions and beliefs, which all refer to teachers' subjective thinking (Hutner and Markman, 2016; Kagan, 1992; Pajares, 1992). 'Belief' and 'conception' are most salient and are interchangeably used in science teacher education literature (Bryan, 2012; Kember, 1997; Pajares, 1992).

Pratt (1992) broadly defined conception as a 'specific meaning attached to phenomena which then mediate our response to situations involving those phenomena' (p. 204). In the context of science education, Hewson and Hewson (1987) defined 'conception' as a 'set of ideas, understandings and interpretations of experience concerning the teacher, teaching, the nature and content of science, and the learner and learning which the teacher uses in making decisions about teaching' (p.194).

Attempts to define 'belief' include Kagan (1992) who defined teacher belief 'as tacit, often unconsciously held assumptions about students, classrooms, and the subject matter taught' (p. 65). More recently, Hutner and Markman (2016) proposed that ‘beliefs are mental representations that influences the practice of a teacher only when a belief is active in the cognition’ (p.675). For consistency, I will use ‘belief’. I subscribe to a view of belief as a part of a collection of mental constructs that forms the structure of human cognition that supposedly drive actions (Bryan, 2012; Dancy and Henderson, 2007). Although people hold beliefs about almost every aspect of the perceived world, teachers specifically hold beliefs about subject knowledge, teachers and teaching, learners and learning, moral, ethical and societal issues (Levin, 2015).

Further, beliefs provide rationale or justification for teachers’ decision and choice of a particular instructional practices (Dancy and Henderson, 2007). Teachers draw on and use their beliefs as a mental screen when making instructional decisions (Pajares, 1992). A hypothetical example of belief could be that whenever teachers ask difficult questions, they call on boys to answer, whereas when they ask simple questions requiring recall, they invite girls to answer. Such teachers could be holding certain beliefs about the intelligence and learning abilities of boys and girls. Overall, research on teacher beliefs focuses on describing teachers’ subjective thinking upon which they draw when making instructional decisions and choices (Thomas et al., 2001).

3.2 Nature of belief: Overview

Literature shows that beliefs exist in a complex interconnected system that is part of an individual’s schemata. These are web-like network of mental representations of reality (Pajares, 1992). It is information represented in the mind such that it can be utilised during mental processes involving thinking, making decisions and choices (Hutner and Markman, 2016). Some beliefs are core while others are peripheral to the individual (Pajares, 1992). Core beliefs are strongly connected and related to other beliefs in the belief system. Strongly connected beliefs are those that individuals acquired through direct experience with ‘belief object’ while beliefs learned from other people are less connected. For example, teachers are more likely to believe in teaching approaches they themselves used to produce desired outcomes.

Core beliefs give a sense of identity to an individual and can be shared among individuals in a community thus inherently important to individuals and the community (Hutner and Markman, 2016). When frequently used in the cognitive processes, a belief becomes increasingly important to a person. This makes it possible for beliefs to occupy different loci in a belief network depending on the extent to which such belief is important to a person. For this reason, conflicting beliefs may co-exist in the belief system (Hutner and Markman, 2016; Pajares, 1992).

Further, beliefs vary in magnitude of vulnerability to change with those assimilated earliest into the belief structure being the most robust and resistant to change than the newly acquired beliefs (Pajares, 1992). This is because pre-existing beliefs affect the perception, processing, and interpretation of the subsequent information required to form new beliefs. In addition, individuals tend to turn conflicting evidence to support the well-established beliefs they already hold contributing to the persistence of the older beliefs and the associated practices (Pajares, 1992). In short, people tend to reinterpret the contrasting evidence in ways that backup the beliefs they already hold.

Since beliefs gradually becomes robust with use, individuals tend to keep beliefs founded on flawed or incomplete information even when confronted with scientifically sound evidence. They tend to hold on their beliefs even when they become aware of the falsity of such beliefs or evidence supporting them. Thus, people do not fully revise older beliefs even when confronted with new evidence. In short, beliefs that individuals assimilate earliest into the belief structure are the most resistant to change. This is because older beliefs influence perception (of new information) which prompt behaviours and actions which reinforce them (Pajares, 1992).

Lastly, Rokeach (1968) observed that people are often unable or unwilling to articulate their beliefs because they are often unconscious of the beliefs they hold. Consequently, understanding teachers' beliefs essentially requires making inferences from what they say, intend and do instead of making direct measurements (Pajares, 1992). This imply that the choice of methods that would allow access to teachers' thoughts, intentions, and actions is inevitable. I discuss formation of teacher beliefs next.

3.3 Formation of teacher beliefs

Literature shows that science teacher beliefs are created and transmitted culturally (Pajares, 1992). Schooling and teaching experience of teachers, teacher education, and cultural context of the school and broader society in which the school is located, all contribute to the formation of teacher beliefs (Kagan, 1992; Eick and Reed, 2002; Luehmann, 2007; Saka et al., 2013). I further discuss these next.

3.3.1 Cultural norms of the society

The culture of the society in which teachers and students get socialised to, shapes the beliefs that underlie their behaviours and practices (Guthrie, 2011). When growing up, individuals are socialised into both explicit and implicit rules of thoughts that govern behaviours in a society. They internalise these habits of thought as their subjective reality, which in turn informs their actions and behaviours (Tabulawa, 2013). Teachers and students who have been exposed to such social processes inevitably embody the habits of thoughts they internalised while growing up in their communities. Such cultural modes of thoughts forms part of the ‘belief baggage’ they bring into learning contexts.

Therefore, a question is ‘what belief baggage do teachers and students bring into the school and classroom contexts in Tanzania?’ Cross-cultural literature shows that societies are dominated either by vertical cultures or horizontal cultures (Schommer-Aikins, 2004). Vertical cultural orientation symbolised by clear hierarchical distinction of people considering age, status and power dominates most African societies including Tanzania (Tabulawa, 2013). Considering this cultural orientation in which teachers (and students) in Tanzania were born, raised and socialised, it is evident that they bring with them certain beliefs about knowledge, teaching, learning and desirable adult-child relationships. Researchers (see Hamminga, 2005; Guthrie, 2011; Tabulawa, 2013) have examined in some details the potential beliefs that teachers and students in the ‘vertical and collectivist’ cultures of Africa might hold. I will outline some of the beliefs that teachers and students might bring into the classroom context and show how these may influence their understanding of knowledge, teaching and learning.

Using a tree model, Hamminga (2005) illustrated African traditional epistemology. According to Hamminga, an African community is analogous to a tree with ‘roots’ representing ‘ancestors’ which give ‘energy’ to the ‘trunk’– the elders. Elders in turn channel the energy to the branches and leaves – the children and grandchildren. Comparably, traditional African societies believe in ‘unified epistemology’ in which all knowledge comes from deities and ancestors – the roots of the community through elders to their children (Hamminga, 2005; Guthrie, 2016). Deities through ancestors reveal all knowledge to elders instead of human intellectual discovery (Guthrie, 2011).

To know an herb for treating unknown illness for example, one needs to offer 'sacrifice' to deities and ancestors to please them and seek their revelation, instead of engaging in labour intensive therapeutic discovery. On revelation, such knowledge of 'herb' comes prefabricated, fixed, practical, and readily usable. It could only be scrutinised and questioned through subsequent revelation but not via human intellectual endeavours such as scientific experimentation. This fundamental belief about source and nature of knowledge influences educational practices and the relation between teacher (elders) and students in the classrooms (Bruner, 1996).

Considering their position in the family tree, elders (the trunk) are closer to ancestors (the roots) than children (the leaves) are. Further, elders lived longer and their age (in African cultures) is directly proportional to the amount of knowledge (wisdom in my culture) accumulated. Since elders possess more knowledge, the society accords them power and privilege to overlook children (Tabulawa, 2013). In short, traditional African society believes elders have accumulated and possess great deal of knowledge or wisdom because of their longer life experiences and closeness to ancestors and deities. In Swahili culture (Tanzania) for example, elders' authority is 'portrayed in the use of the term *wazee* (elders/old people) where the connotations of being honourable, respectable and knowledgeable are inherently part of the meaning itself' (Kresse, 2009, p. 151).

Tabulawa (2013) argued that by default children must learn from adults since it is practically impossible for them live longer and accumulate more knowledge than adults. Indigenous African education therefore involved transfer of knowledge from elders to children. Traditionally, teachers therefore considered children to have no or little understanding thus expect no legitimate knowledge contribution from them (Mushi, 2009). It is this teachers' ascription of ignorance to children that motivates effort to teach (Bruner, 1996). Therefore, the pedagogical belief underlying traditional education is that the learner is ignorant of 'what is to be learned' and this can be conveyed by telling.

Teaching involved transfer of 'general knowledge' to every young member of the society depending on sex and gender and 'secret sacred knowledge' to the few selected individuals (Mushi, 2009). Children learned through drill, recitation, drama and storytelling, the general technical knowledge about hunting, gardening, and warfare as part of their upbringing. Further, motivation through scolding, threatening, beating and punishing for undesirable behaviours characterised teaching (Mushi, 2009).

Children learned sacred knowledge through initiation, ritualism, sacred rites and sorcery. During the learning process, the novice was expected to watch and listen faithfully to elders who possessed knowledge. Obedience and submissiveness were esteemed while disobedience was highly discouraged through severe punishment. These social structures and child rearing practices reinforces domination of adult and subordination child in the African cultures (Tabulawa, 2013). Elders for example, discouraged questioning and critiquing cultural norms and values that has been preserved for generations (Mushi, 2009). Indeed, literature shows that traditional education in Tanzania had a body of knowledge that never changes. Instead, traditional education concentrated mainly on transmitting cultural heritage with minimal intellectual imaginations and thinking beyond the tribal norms and values (Mushi, 2009). A question however could be 'what implications do beliefs about children, cultural knowledge and learning described so far have on the adoption of learner-centred pedagogy in Tanzania?'

First, most of these cultural beliefs contrast the principles underlying learner-centred pedagogy emphasised in the teacher education programmes in Tanzania. Cultural conception of knowledge as externally located body of norms and values that pre-exists a child conflicts learner-centred view of learning as construction of knowledge based on learners' prior experiences and understanding. Socialised into cultural ways of knowing, teachers would possibly see themselves as knowledge repositories and expect students to be docile recipients. In the classroom context, subject content of science may be analogous to unquestionable truths revealed to teachers (elders) or sacred knowledge from ancestors. This is evident in the widespread use of traditional Swahili proverbs such as 'kuishi kwingi ni kuona mengi' (those who lived longer have seen or experienced much, *my translation*) or 'macho yaliyoona milima hayashtukii mabonde' (those who have seen much are not amazed as those who have never seen beyond the ordinary) which reinforces the attribution of knowledge to elders.

Learners socialised into these 'cultural habits of thought' are likely to assume that teachers have knowledge and would pass it to them. They may not recognise that they themselves have knowledge or could construct knowledge through sharing. Thus, they may not recognise the responsibility they have for their own learning and thinking. Further, seeing cultural knowledge as a 'sacred good' is likely to influence teachers and students understanding of progressive ideas such as collaborative co-construction of knowledge through dialogue based on justifications and logical reasoning. Indeed, Mushi (2009) argued that although reasoning was imperative for individuals to make meaningful decisions, abstract thinking beyond the will of the god of a tribe was insufficiently developed under traditional education.

Second, a view of cultural knowledge as something that could only be passed on through ritualism, sacred rites, and sorcery contrasts with constructivists' view of knowledge as something created and recreated through intellectual efforts involving critical thinking, independent inquiry, questioning and critical assessment. In fact, constructivists' ideas such as scepticisms, hypothesising, scrutinising and debating were not inherent in the traditional African epistemology and were discouraged (Hamminga, 2005; Tabulawa, 2013). As Mushi (2009) pointed out, the aim was to transmit as faithfully as possible, the valued knowledge and desired ways of life instead of questioning, refuting and deconstructing them.

Lastly, the nature of traditional teaching characterised by drill and recitation reinforced with scolding, threatening, encouraging, bribing, and punishing might influence teachers and students' perceptions of teaching and learning grounded in learner-centred principles. For example, while learner-centred pedagogy stresses a safe discursive environment in which students actively participate and contribute ideas, traditional teaching values and reinforces obedience, submissiveness and faithful listening to instructor.

Overall, if teachers bring these contrasting beliefs about knowledge, teaching and learning into teacher education, their understanding of the intended teaching reforms might be influenced. Further, if these prior beliefs remain unaltered during teacher education, they might subsequently influence the actual practices of teachers. In the next section, I focus on the influence of the school socio-cultural context on teachers' beliefs.

3.3.2 Socio-cultural context of the school

Literature shows that the culture within the school in which teachers teach mediate the acquisition of beliefs (Hofer and Pintrich, 1997). The physical environment including the structure of the instructional spaces and the norms and expectations inherent in the school reinforces the formation of certain beliefs and supresses others (Nargund-Joshi, Rodgers and Wiebke, 2014).

For example, teacher educators may endeavour to inculcate in teacher candidates, the beliefs supportive of learner-centred teaching, yet schools employing newly qualified teachers may promote countervailing values thereby supressing the beliefs learned during teacher education (Westbrook et al., 2009). Research has established how school administrators, peer teachers, students and classroom designs compel ‘novices’ to abandon the reform ideas they acquired during the teacher training thereby regressing to the folk beliefs and practices (Bruner, 1996; Rodgers and Scott, 2008; Saka et al., 2013).

School administrators for example, normatively determine the ‘standard teaching practices’ and demand compliance of teachers under their authority (Rodgers and Scott, 2008). Thus, the key principles and ideas about learner-centred pedagogy that teachers acquire during teacher education are subjected to prescriptive bureaucratic demands and expectations. Saka et al. (2013) for example, demonstrated how bureaucratic directives that required teachers to dedicate part of the lessons to drilling students impeded beginning teachers from implementing learner-centred teaching ideas they learned during teacher education. Similarly, Levin et al. (2013) observed that beginning teachers abandoned their enthusiasm for differentiated learning because it conflicted with school norms that emphasised drilling students using past exam items in preparation for high-stake exams. These administrative orders coupled with a lack of support and expectations for beginning teachers to obediently carryout school rules, values, and routines as directed intensifies ‘wash out’ effect and conformity to prevalent norms (Westbrook et al., 2009). Overall, the prevailing school structures favoured traditional beliefs about teaching. Consequently, teachers retained and enacted such beliefs while they abandoned ideas they learned during teacher education shortly after they started teaching.

Rodgers and Scott (2008) thus argued that teachers should recognise that within each school context there exist a set of norms often determined by authorities superior to them that they should have to abide and uphold against their will. This is typically relevant to Tanzanian teachers who are often encouraged to implement interactive pedagogies that promote deeper learning, yet they are demanded to cover mandate content and prepare students for exams (Vavrus, 2009).

Community of practice also powerfully shapes teachers’ beliefs because teachers often develop a sense of belongingness by affiliating to a community of colleagues who teach similar subjects and grade levels. When they join teacher communities, beginning teachers acquire beliefs from peers and experienced colleagues. Rodgers and Scott identified two ways in which teachers acquire beliefs from peers.

First, during their early career, teachers often take cues, seek approval and feedback from their surrounding as a measure of how well they are teaching (Rodgers and Scott, 2008). When they reflect on their teaching, they self-appraise their practices in relation to the expectations and practices of the ‘seniors’ in their respective communities. In other words, they avoid being the ‘only one’ holding on and practising certain beliefs about teaching and learning. In this way, they conform to the mainstream beliefs that all community members share. Second, newly qualified teachers often seek support and approval of senior teachers for the ideas they bring into teaching. Senior teachers' support reinforces and strengthen such beliefs thereby promoting beginners to develop confidence to enact their ideas (Avraamidou, 2014b; Levin et al., 2013).

Substantial body of research however, shows that beginning science teachers are less likely to find in schools, the beliefs and practices that support teaching ideas advocated in colleges (Luehmann, 2007; Nargund-Joshi, et al., 2014). Instead, they often encounter criticism from resistant senior colleagues for enacting new ideas about science teaching they acquired during teacher education (Luehmann, 2007; Westbrook et al., 2009). They are often criticised and stigmatised for trying out innovative science teaching ideas when such ideas are not appealing to senior teachers (Pedretti et al., 2008). Although initially beginning teachers may be strongly enthusiastic to innovative ideas, eventually they realise such ideas are misaligned to the models of teaching senior peers value and practice. Consequently, beginning teachers abandon such beliefs and conform to the expected norms and practices.

Students' behaviours also shape classroom processes and significantly influence the models of pedagogical practice teachers consider feasible in their classroom contexts (Tabulawa, 2013). Using evidence from Botswanan classrooms, Tabulawa demonstrated how students strategized overtly and covertly to keep teachers in a knowledge delivery role thereby enhancing teachers' control over teaching and learning process. This suggest that students could constrain teachers' attempts to enact approaches that engage and relegate them learning responsibility. Literature in other contexts largely confirm the influence of students on teachers' beliefs. In US, Eick (2009) found unruly and off-task students' behaviours militated against teachers' attempts to enact teaching ideas that reflect learner-centred methods. Such unsupportive behaviours accelerate 'wash out' effect on innovative ideas.

Generally, the literature concurs with Bruner (1996) who argued that any pedagogical innovation introduced in the classroom will inevitably compete with the 'folk beliefs' of learners. Together with the norms and expectations that school administrators and senior teachers' support, folk beliefs create a school context that militate against the implementation of reforms ideas that beginning teachers acquire during teacher education. I discuss the influence of past schooling experiences next.

3.3.3 Past schooling experiences

Before joining teacher education, teacher candidates have been students for considerable number of years (over 13 years in Tanzania). During this period, teacher candidates develop images of good science teaching by emulating the practices of their own science teachers (Buehl and Fives, 2009). Teacher beliefs and images formed due to 'apprenticeship of observation' (Lortie, 2002) have powerful and resilient impact on student teachers, which far outweigh the impact of teacher education thus difficult to transform (Danielsson and Warwick, 2014; Eick and Reed, 2002; Levin and Ye He, 2008; Pajares, 1992). According to Levin and Ye He (2008) for example, a large proportion of teacher candidates attribute their beliefs about teaching, learning and subject matter to their secondary education experiences.

Former teachers form a crucial aspect of schooling experiences and influence teacher candidates' views of good teaching (Flores and Day, 2006). Teacher candidates acquire a great deal of beliefs through observation and imitation of teachers they admire during schooling, which in turn influences their pedagogical choices. They often refer to the teaching they experienced as students when teaching their classes. While some teachers may change the practices of their own teachers they dislike, others replicate them (Flores and Day, 2006). For example, teachers who experienced learning science through lecture-based strategies such as drilling and memorising textbook content advocate and employ such strategies during their own teaching (Eick and Reed, 2002; Nargund-Joshi, et al., 2014). These teachers have confidence in traditional teaching strategies because they productively learned through the same during schooling (Nargund-Joshi, et al., 2014).

Similarly, traditional images of science teacher as an authority figure conveying knowledge is often built on teachers' past schooling experiences (Danielsson and Warwick, 2014). Such images of 'traditional teachers' often constrain beginning teachers from developing confidence in the principles and practices of learner-centred pedagogy for they lack exposure to such practices from their own schooling (Westbrook et al., 2009). Lastly, the design of the teacher education programme also determines its' impact in changing the images of teaching that teacher candidates bring into teacher education as discussed next.

3.3.4 Teacher education

Literature indicates that teacher education may have a weak impact on student teachers and may tend to propagate the images of teaching they formed during schooling (Flores and Day, 2006; Pajares, 1992). For example, Park et al. (2010) monitored changes in teacher beliefs throughout teacher education trajectory that aimed at helping teacher candidates develop constructivists' beliefs about teaching science. They elicited student teachers to reflect on their beliefs and practices using conceptual change approach. Results showed that teacher candidates retained their traditional beliefs about science teaching throughout the programme. They hardly fully revised the beliefs they brought into teacher education.

Likewise, Brown and Melear (2006) traced the changes in student teachers' beliefs throughout teacher education programme that emphasised inquiry methods and subsequently during the first three years of teaching career. Even after three years of teaching, participants maintained strong belief in transmissive teaching, which demonstrates that fostering teachers develop beliefs aligned with the aspired teaching reforms is challenging for teacher educators. Conversely, chances are high for teachers regressing to the older beliefs when they begin teaching in schools as full time teachers (Akyeampong et al., 2006; Markic and Eilks, 2013). This is because teachers tend to take for grant and absorb much of the values and norms they see in the school context without reflecting (Rodgers and Scott, 2008).

A growing body of literature however, indicates the possibility of designing teacher education to offer trajectories geared at transforming pre-existing beliefs (Brownlee et al., 2001; Bryan, 2012; Hutner and Markman, 2016). Teacher education can successfully transform teachers' beliefs by explicitly encouraging student teachers to reflect on their beliefs and offering them 'alternatives' upon which they can draw (Brownlee et al., 2001). By explicitly reflecting on their prior beliefs, student teachers experience cognitive dissonance and develop more sophisticated beliefs (Piaget, 1985). Tsai (2006) reported about a teacher education programme that exposed student teachers to instructions on philosophy of science and conceptual change theories and successfully transformed their beliefs about science knowledge and teaching. Student teachers who took part in the programme reinterpreted their views of scientific knowledge and how it should be taught. In another intervention, Levin et al. (2013) employed personal theorising process to encourage student teachers to reflect on their beliefs about teaching. Researchers asked student teachers to articulate their beliefs and evaluate if they had evidence to justify and enact such beliefs. Consequently, after reflections, participants revise the beliefs they could not support.

Collectively, these studies have shown how teacher education equipped with trajectories that require teachers to articulate, reflect and interrogate their beliefs can transform pre-existing beliefs and contribute to developing sophisticated beliefs. This should explicitly focus on scaffolding student teachers to reflect consciously on their beliefs. Such attempts to change teacher beliefs should go with support by teacher educators (Avraamidou, 2014b; Hutner and Markman, 2016). Changing science teacher beliefs however, remain complex even with well-intentioned interventions particularly when school structures are contradicting the desired beliefs and practices (Buehl and Fives, 2009). Context-based cycles of reflection and analysis of teaching during initial and in-service teacher education is crucial (Bryan, 2012). I discuss the role of teaching practice next.

3.3.5 Teaching practice experiences

Research recognises field teaching practice as an important source of beliefs about teaching and learning (Buehl and Fives, 2009; Flores and Day, 2006; Levin and Ye He, 2008). The first teaching practice experience whether during field placement or fulltime teaching job, greatly influences the beliefs student teachers hold and eventually the way they teach science (Flores and Day, 2006). Such influence occurs in two ways.

First, during the theory part of teacher education, student teachers learn idealistic views of teaching including principles of learner-centred pedagogy. When placed in schools for field practice, student teachers often attempt to enact their idealistic teaching ideas expecting to have perfect lessons that squarely fits their theories. This is largely not the case, because attempts to enact idealistic teaching often clash with the real classroom practical problems like disruptive students (Flores and Day, 2006). On realising that their beliefs are impracticable or incompatible with the real classroom context, student teachers often turn to on the spot pedagogical decisions. Gradually, they abandon the conflicting beliefs they hold while ingraining (into their practices) the beliefs supported by the existing school structures. When employed as full-time teachers in the same schools, most of such beliefs become well-established and fixed. These serves not only as the basis for instructional decisions but as part of teachers' self and identity (Levin et al., 2013).

Second, cooperating teachers influence student teachers more than college teaching practice supervisors (Kagan, 1992). This is because during the field placement student teachers observe lessons taught by cooperating teachers and learn great deal of teaching beliefs from them. While some cooperating teachers reinforce the beliefs teacher candidates acquire during teacher education, most others give contradictory comments and feedback to student teachers during field teaching (Avraamidou, 2014b). Such contradictory remarks challenge the beliefs that support teacher candidates idealistic teaching forcing them to lose confidence or abandon their idealistic practices all together. Mentor teachers are often sceptical and less amenable to novel teaching, thus they often interrogate student teachers for implementing innovative practices (Avraamidou, 2014b; Westbrook et al., 2009). This often lessens student teachers' confidence in effective teaching that prioritise deeper understanding, because such teaching contrasts mentors' expectations (Westbrook et al., 2009). In short, field teaching experience largely reproduces the ineffectual teaching practices (Kang, 2008).

Research in sub-Saharan Africa shows that the supervision of field teaching practice is often rushed, irregular and mostly focused on assigning numerical grades (Hardman et al., 2012). This deprives student teachers of the supervisors' support they need to enact the teaching ideas they acquire during the training. It also maximises the chances of them regressing back to the conventional teaching ideas that the school context often supports. Lastly, belief change can be triggered by confronting student teachers with alternative ideas as discussed next.

3.3.6 Cognitive disequilibration

The integrated model of belief change (Rule and Bendixen, 2010) explains Piagetian cognitive disequilibration process of belief change and formation. Underlying such a model is the assumption that belief change results into formation of new beliefs. Rule and Bendixen proposed that the revision of pre-existing beliefs and advancement might occur when individuals experience cognitive conflicts by doubting the beliefs they hold. The process involves questioning ones' own beliefs and taking charge in making judgement and choices. Researchers described this as taking volitional control in which individuals act accordingly when they experience doubts about their beliefs. After evaluating their beliefs, individuals then enact resolution strategies to change beliefs. This however, depends on previously experienced doubts about the beliefs and volitional control. There is a possibility, both for the advancement of beliefs or regressing back to the old beliefs.

Beliefs that other individuals in the environment hold also influences the formation of personal beliefs. This means both school structures and personal beliefs exert reciprocal influences on each other (Rule and Bendixen, 2010). This partly explains why beginning teachers abandon the ideas about teaching and learning they acquire during teacher education shortly after they assume a full-time teaching (Flores and

Day, 2006; Avraamidou, 2014b). Such beliefs are conflicted by those held by other teachers, students and school administrators.

Two inherent shortcomings are evident in the mechanism of beliefs formation via the Integrated model. First, although Rule and Bendixen acknowledge the role of emotion in the belief acquisition and change, they have not clearly explicated the mechanism by which this takes place. Second, the model does not explain what prompts individuals to doubt or question their pre-existing beliefs. One explanation based on cognitive disequilibration mechanism (Piaget, 1985) is that when belief under which an individual operates is incongruent with the experiences in the environment, a person experiences cognitive dissonance. This prompts the individual to doubt and question such beliefs and subsequently revise it. Overall, forming new beliefs through the Integrated model (Rule and Bendixen, 2010) requires teachers to engage in meta-cognition by reflecting and evaluating their beliefs to make choices.

3.4 Argument for teachers' beliefs in teaching reforms

The value of taking teacher beliefs into consideration when attempting to reform the practices of teachers is increasingly being acknowledged (Bryan, 2012; Fives and Buehl, 2016). Teacher belief is worth considering by those eager to optimise chances of successful teaching reforms for several reasons.

Teachers candidates join teacher education with well-founded beliefs formed because of schooling experiences (Lortie, 2002). Such beliefs are often robust and resistant to change because teachers have grown up with them (Pajares, 1992). They influence the learning of the reform ideals that teacher educators expect beginning or experienced teachers to learn. For this reason, teacher educators need to engage with the beliefs that teachers bring into training before confronting them with new teaching ideas (Fives and Buehl, 2016).

It is widely acknowledged that when teachers' beliefs contrast with the principles and assumptions of the reforms, teachers often reject the reforms or implement them superficially (Bryan, 2012; Yerrick et al., 1997). Conversely, when such principles and assumptions coincide with their beliefs, teachers are more likely committed to adopting teaching reforms (Levitt, 2002). This is because teacher belief serves as a decisive factor for the teaching strategies and content knowledge that teachers chose when teaching (Waters-Adams, 2006). Hence, teacher educators and teaching reformers seeking to promote pedagogical renewal in Tanzania should explore teachers' beliefs to salvage teaching reforms from predestined failure.

Overall, the importance of considering teacher belief when reforming teaching has been summarised by Levin (2015) who argued that policy makers often wonder why teachers rarely enact teaching reforms with fidelity. For Levin, the reason is teachers' resistance, which stem from their well-ingrained beliefs. Teacher belief influence how and why teachers may or may not change their practices to reflect reformers' vision of effective teaching. In what follows, I discuss relevant beliefs in the context of teaching reforms.

3.5 Relevant beliefs in the context of teaching reforms

Although teachers hold beliefs about almost everything that schooling is set out to achieve, teacher beliefs about knowledge, teaching and learning are the most salient when reforming their practices (Fives and Buehl, 2016). I consider that such beliefs might have supported or constrained the learning, and implementation of the learner-centred teaching reforms in Tanzania.

3.5.1 Beliefs about science knowledge

Beliefs about knowledge constitute ideas individuals hold about knowledge and knowing (Hofer, 2001). For Hofer, these encompasses what count as knowledge, how it is created and evaluated, where knowledge resides and how knowing occurs. Beliefs about knowledge has been theorised differently.

In his seminal work, Perry (1970) proposed a stepwise development of epistemological belief, which begins with dualism, multiplism, relativism, and ultimately commitment within relativism. Dualists conceptualise knowledge in terms of simple right or wrong. They believe in the existence of knowable absolute truth. In contrast, Multiplist view knowledge as a tentative diverse point of views (Hofer, 2001). Relativists believe these diverse views are equally valid and eventually committed relativists begin to recognise variation in superiority amongst the diverse viewpoints (Hofer and Pintrich, 1997).

In the 1990’s Schommer introduced a systemic model in which she theorised epistemological belief as a system of more-or-less independent beliefs. Schommer categorised people’s beliefs about knowledge on a continuum of naïve to sophisticated beliefs basing on the dimensions of *source, structure, stability, speed, and ability of knowing (*emphasis added) (see table 3.1).

Table 3.1: Categories of beliefs about knowledge (Schommer, 1990)

Dimension	Naïve belief	Sophisticated belief
Structure	Fragmented bits of concepts	Integrated set of concepts
Stability	Unchanging/Certain	Ever changing/Uncertain
Source	Authority/expert	Evidence and reasoning
Speed of knowing	Quick all or none	Gradual
Ability of knowing	Fixed at birth	Improvable with time/experience/effort

According to Schommer, individuals who hold naïve beliefs perceive knowledge as simple, certain and stable facts handed down by omniscient experts. They believe that ability to know is innate thus knowing is either quick or none existent. In contrast, people who hold sophisticated beliefs perceive knowledge to be uncertain, tentative and interrelated concepts progressively created and recreated based on reasoning and evidence (Schommer, 1990). Recently, Schommer advocated balancing the magnitude of epistemological belief sophistication rather than relying on the extreme dualism or relativism (Schommer-Aikins, 2004). She theorised that epistemological beliefs are more meaningful when conceived as a frequency distribution with some individuals holding more basic level or naïve belief and others holding higher-order or sophisticated beliefs (Schommer-Aikins, 2008).

Research exploring the influence of science teachers' beliefs about knowledge on their practices consistently demonstrated that teachers holding a naïve view of scientific knowledge tend to favour teacher-centred transmissive teaching, whereas, those holding sophisticated beliefs about scientific knowledge tend to embrace learner-centred constructivist pedagogy (Çetin-Dindar et al., 2014; Kang and Wallace, 2005; Mansour, 2013; Markic and Eilks, 2013; Park et al., 2010; Yerrick et al., 1998).

Literature shows that teachers who accord high status to scientific knowledge, seeing it as a body of facts representing absolute truths prefer teaching science by propagating factual knowledge (Park et al., 2010). They perceive science as verified facts that students need to accumulate, thus for them teaching is transmitting knowledge through lecturing and recitation strategies (Mansour, 2013). These teachers often intersperse lecturing of subject content with close questions seeking to ascertain if students had mastered scientific facts they need to acquire (Lemberger et al., 1999; Meyer et al., 1999).

Conversely, research shows that science teachers holding sophisticated epistemological beliefs prefer constructivist learning environment (Çetin-Dindar et al., 2014). These teachers advocate learner-centred constructivist strategies including giving opportunities to experience uncertainty of scientific knowledge and encouraging collaborative and interactive construction of knowledge by connecting classroom science with everyday experiences. For example, Glackin (2016) found that British teachers holding sophisticated conceptions of science successfully implemented authentic science lessons in which students constructed their understanding based on experiences, observations, and dialogue. This evidence suggests that learner-centred pedagogy could be favoured in contexts where teachers hold sophisticated views of science. I now turn to beliefs about teaching.

3.5.2 Beliefs about teaching science

Science teachers hold beliefs about teaching, its purpose and the role of students and teachers during teaching (Gao and Watkins, 2002). One popular approach to conceptualising teacher beliefs about teaching is to cluster beliefs into teacher-centred and learner-centred categories following Kember (1997). Based on an extensive review of literature on teacher beliefs about teaching and learning Kember developed his framework by clustering teacher beliefs into two contrasting categories. Trigwell et al. (1994), and Prosser et al. (1994) also proposed similar categories.

Although classifying teacher beliefs about teaching into learner-centred and teacher-centred beliefs suffers oversimplification (Belo et al., 2014), Kember's approach remains a heuristic tool for describing beliefs held by varied group of teachers (Fives and Buehl, 2016). Further, to overcome simplicity, Kember subdivided the two broad categories into five subcategories ranging from teaching as imparting knowledge to teaching as facilitating conceptual change (figure 3.1).

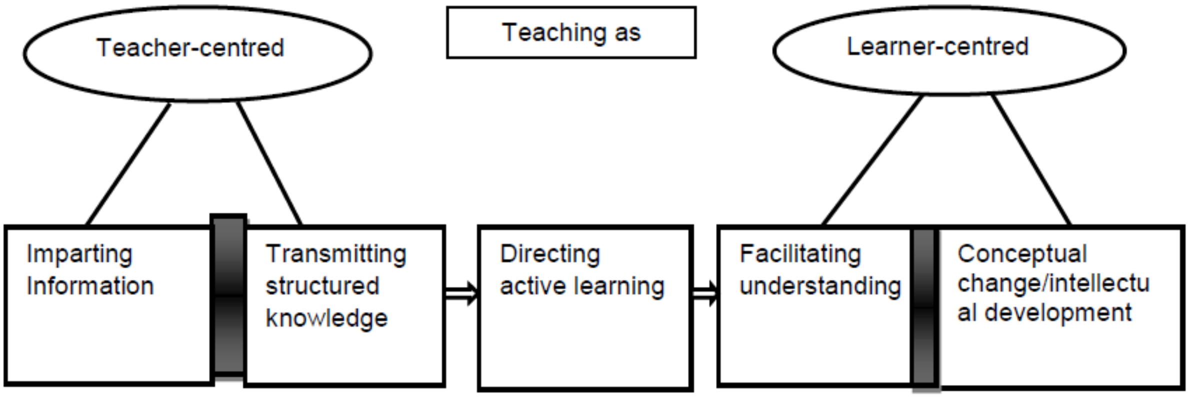


Figure 3.1: Categories of beliefs about teaching (Kember, 1997, p. 264).

Teacher-centred belief is symbolised by focus on delivery and transfer of knowledge from a teacher to students in the form that they can easily accumulate. In contrast, learner-centred teachers see teaching as facilitating students to make sense of knowledge thereby transforming their understanding. Further, students' passive role in accepting knowledge under a teacher-centred view contrasts with their active role in processing information and constructing knowledge under learner-centred conception (Fives and Buehl, 2016; Lingbiao and Watkins, 2001).

Amid the two broad categories, rests teaching as directing students' activities, which is a transitionary link between sub-categories of the two broad categories. Kember theorised that the transition between the two broad categories requires a radical change whereas the transition between sub-categories of the same broad category is relatively easier because the boundaries are diffuse as shown by the shaded area. Further, the belief categories have neither rigid nor fixed boundaries because individuals can hold beliefs that fall in different categories. Thus, the categories are established positions along the continuum (Kember, 1997).

Other attempts to explore and categorise teacher beliefs about teaching created similar categories (Boulton-Lewis et al., 2001; Gao and Watkins, 2002; Koballa et al., 2005; Lingbiao and Watkins, 2001). These largely confirmed Kember's initial model except for minor modifications. For example, Boulton-Lewis et al. (2001) categorised beliefs about teaching held by Australian teachers into teaching as transmitting content, developing skills, facilitating understanding and transforming students' thinking. Based on Kember, Boulton-Lewis and colleagues proposed that the categories in their framework represent a continuum of beliefs about teaching ranging from teaching as teacher-centred transmission of knowledge to learner-centred teaching focused on transforming students' understanding.

Further, Lingbiao and Watkins (2001) and Gao and Watkins (2002) categorised the Chinese physics teachers' belief about teaching into knowledge delivery, exam preparation, ability development, attitude promotion and conducting guidance. They further clustered these lower order categories into higher order teaching orientations. Thus, knowledge delivery and exam preparation formed the *moulding orientation* whereas ability development, attitude promotion and conducting guidance formed the *cultivating orientation.* In South Africa, teachers mainly perceived 'teaching as transferring scientific knowledge from the mind of the teacher to that of the learner' while few advocated 'creating space for the learner to develop understanding' (Taylor and Booth, 2015, p. 1).

Fundamentally, most of the categories fall within Kember's model with slight variation in characterisation of subcategories. All the categories of beliefs proposed by Lingbiao and Watkins (2001) for example reflect Kember's model except teaching as exam preparation. For example, teaching as knowledge delivery is very similar to imparting information or transmitting structured knowledge in Kember's framework. In both categories, teaching is viewed as transmitting knowledge from external sources for students to passively accept. Emphasis on passing students in public exams however symbolises teaching as exam preparation. Under such conception, examination dictates the content and methods of teaching. This indicate the influence of public exams on teacher beliefs about teaching in Chinese secondary education context. Taylor and Booth also contrast Kember's model because South African science teachers hardly espoused teaching as facilitating conceptual change, which is the most advanced view of teaching.

Teachers' beliefs about teaching are largely related to their teaching practices (Brown and Melear, 2006; Chen et al., 2012; Koballa et al., 2005; Lemberger et al., 1999; Levitt, 2002; Mansour, 2013). Research shows that teachers who espouse beliefs in traditional teacher-centred pedagogy display practices and behaviours consistent with their professed beliefs. For example, Koballa et al. (2005) found that teachers in their study perceived teaching science as presenting and covering science content as faithfully as prescribed in the mandated textbooks. These teachers believed selecting segments of the curriculum that students are supposed to learn and prescribing learning strategies was within their authority. For them, the purpose of teaching science is to enable students to pass tests and assignments. Consistent with their beliefs, these teachers focused on delivering content knowledge and encouraging students to memorise facts (Koballa et al., 2005). Further, they asked closed factual questions to ascertain if students remember content knowledge. Their classroom organisation was characterised by desks arranged in rows to optimise the visibility of teacher and chalkboard to students. When teaching, they maintained greater control of students to minimise disruption and maximise attentive listening (Brown and Melear, 2006).

Likewise, teachers who professed beliefs in learner-centred pedagogy exhibited teaching behaviours consistent to their espoused beliefs (Brown and Melear, 2006; Koballa et al., 2005). These teachers espoused teaching that begins with exploring students' prior knowledge and misconceptions. For them, teaching should focus on helping students construct multiple perspectives of scientific ideas instead of narrowing learning to the accumulation of prescribed curriculum content (Koballa et al., 2005). These teachers valued teaching and learning that promote the development of deeper understanding and interconnectedness of scientific concepts. Thus, they advocated interactive teaching in which a teacher participates as a co-constructor of knowledge rather than dispenser (Brown and Melear, 2006). These teachers expressed enthusiasm in helping students understand and apply science knowledge in real-life (Koballa et al., 2005). Further, they advocated flexible classroom seating arrangements such as semi-circle and horse shoe, which maximise teacher-student and student-student interactions (Brown and Melear, 2006).

Consistent with their beliefs, these teachers demonstrated learner-centred teaching practices. They used a conceptual approach to teaching and learning in which they explored students' prior misconceptions, clarified them and redirected their learning. In doing this, they asked many questions to get deeper into students' prior understanding. Further, they organised classrooms in a semi-circle seating arrangement to optimise classroom interaction (Brown and Melear, 2006). Their classrooms were very interactive with students exploring materials to generate ideas (Koballa et al., 2005). Students were engaged in varieties of hands-on activities such as dissecting frogs, testing air pressure with bottles and eggs. When teaching, they often helped students link lessons to real-life using concrete examples

(Glackin, 2016). Collectively, this literature demonstrates how teachers' beliefs closely coheres with their teaching practices.

A growing body of research however, suggests complexity in the way beliefs influence teaching practices (Bryan, 2012; Mansour, 2009; Park et al., 2010). Literature shows that teachers' beliefs about teaching may not manifest directly in their teaching practices (Koballa et al., 2005). In their study, Koballa et al. (2005) reported that some participants advocated for teaching characterised by two-way interaction between teachers and students with students leading and taking control of the teaching and learning process. Yet, these teachers lectured to give information they wanted students to acquire during their actual classroom lessons. Some teachers expressed their desire to explore students' misconceptions of scientific concepts because they saw these as a foundation for building new knowledge. However, such teachers gave little attention to students' prior conceptions of scientific ideas in both planning and executing their lessons (Koballa et al., 2005). In another study, Lemberger et al. (1999) found teachers expressing sophisticated conceptions of teaching science as facilitating students' understanding yet, their lessons were structured. They maintained control of subject content and allowed limited students' contribution.

Evidence suggests that the translation of teacher beliefs into practice could be influenced by schools structures thereby causing a discrepancy between beliefs and practices (Brown and Melear, 2006; Mansour, 2013; Park et al., 2010). Common influential factors include large class sizes, administrative decisions and students' learning culture (Brown and Melear, 2006).

For example, even when teachers recognise the value of inquiry activities in learning science, they may resort to transmissive approaches when the class is large and students are reluctant to assume responsibility for their own learning (Brown and Melear, 2006). Further, students often resist inquiry learning approaches when these conflict with their learning culture thereby compelling teachers to abandon such practices. Other school related factors such as high-stake exams, teachers' background experiences, availability of resources, mentor teachers and colleagues are also recognised to influence transposition of teachers' beliefs into practice (Mansour, 2013; Park et al., 2010).

3.5.3 Beliefs about learning science

Beliefs about learning and learners that teachers hold influences not only what and how students are taught but the kind and strategies of learning that teachers promote (Brown et al., 2008; Trigwell and Prosser, 1996). Following Säljö (1979), Marton and colleagues (1993) clustered beliefs about learning into six categories considering the magnitude of sophistication. These include learning as; 'increase in knowledge, memorizing, acquisition of facts, abstraction of meaning, interpretive process of understanding and conceptual change'. These are further categorised into higher level clusters of 'cumulative' and 'constructive' beliefs about learning (Brown et al., 2008; Entwistle and Peterson, 2004).

Cumulative view encompasses beliefs about learning as accumulation of facts through memorisation. Leaning under this category involves listening to teachers, reading books, memorising, and reproducing knowledge on demand. In contrast, constructive view encompasses beliefs about learning as processing knowledge to develop and transform learners' understanding (Brown et al., 2008; Entwistle and Peterson, 2004; Trigwell and Prosser, 1996). Learning under this category involves understanding, developing, and abstracting meaning from information learners encounter (Entwistle and Peterson, 2004).

There are similar attempts to explore and cluster beliefs about learning (Boulton-Lewis et al., 2001; Dikmenli and Cardak, 2010). Despite slight variation in the number of categories, these studies largely confirm seminal work by Säljö. Boulton-Lewis et al. (2001) for example categorised teachers' beliefs about learning into four categories including learning as a) acquisition and reproduction of content, b) development and application of skills, c) development of understanding and d) transforming learners. In an earlier research, Prosser et al. (1994) grouped beliefs about science learning among academics into five categories ranging from learning as accumulation of information at the lowest level to learning as conceptual change at the highest level. Leaning as acquisition and reproduction of knowledge for example is equivalent to learning as increase in knowledge in Säljö's initial framework. In both cases, learning involves quantitative increase in knowledge, which constitutes textbooks facts.

Teachers' beliefs about children's minds and how they learn is central to the notions of cumulative and constructive learning (Bruner, 1996). Teachers who view children's minds as ignorant containers that needs filling with expert knowledge tend to promote passive and surface learning. They employ drill and memorisation strategies to promote knowledge acquisition and recall (Koballa et al., 2000; Mansour, 2013). The desire to have students receive and accumulate knowledge from external sources motivates teaching (Koballa et al., 2000). When teaching, these teachers promote passive learning strategies to facilitate memorisation of textbook facts (Mansour, 2013). They rarely encourage students to contribute ideas and even when they do so, the ideas are often based on textbooks rather than personal experiences (Koballa et al., 2000).

Conversely, teachers who view children as thinkers capable of generating ideas promote constructive learning through active pedagogy. They employ active learning strategies such as discussions, dialogue, inquiry, and problem solving, which are effective at fostering constructive learning (Koballa et al., 2000; Mansour, 2013). For them, learning is an active discovery and a construction of knowledge based on students' prior understanding (Koballa et al., 2000; Mansour, 2013). The need to explore what students already know and direct new learning through active interaction motivates teaching (Koballa et al., 2000). In this way, teachers serve as facilitators of learning through active construction of meaning. When it comes to the actual lessons, these teachers encourage active participation and contribution of ideas and experiences during the lesson (Koballa et al., 2000; Mansour, 2013). They use common examples and illustrations to help students connect classroom learning to daily life experiences thereby promoting understanding (Mansour, 2013).

Bruner (1996) boldly stated the thesis emerging from the foregoing literature when he argued 'educational [teaching] practice in the classroom is premised on a set of folk beliefs about learners' minds, some of which may have worked advertently towards or inadvertently against the child's own welfare. These needs to be made explicit and … examined' (pp. 49-50). This substantiates the relationship between teachers' beliefs about learning science and their actual practices. Teachers' beliefs about learning are related to beliefs about science knowledge and teaching forming a system of internally coherent beliefs. I discuss this interplay next.

3.6 Nested beliefs

Science teachers' beliefs about science knowledge, teaching and learning are interwoven (Otting et al., 2010; Trigwell et al., 1994; Tsai, 2002). Studies show that teacher-centred beliefs about teaching science are closely associated with cumulative views about learning (Al-Amoush et al., 2013; Boulton-Lewis et al., 2001; Koballa et al., 2000). When teachers view teaching as transmitting knowledge, they also see learning as accumulating knowledge (Koballa et al., 2000). A survey of Turkish teachers found that teachers holding teacher-centred beliefs about teaching science as transmitting knowledge also perceive learning science as a memorising, passing tests, calculating and practising (Bahcivan and Kapucu, 2014). They advocate teacher-led teaching strategies in which a teacher performs most activities while students passively watch, listen and memorise the subject content (Al-Amoush et al., 2013). Generally, these teachers believe teaching is transmitting content knowledge and learning is the acquisition and reproduction of such knowledge (Boulton-Lewis et al., 2001).

Similarly, literature shows that belief in learner-centred teaching is associated with constructive beliefs about learning science (Al-Amoush et al., 2013; Boulton-Lewis et al., 2001; Koballa et al., 2000). For example, teachers who view teaching as interacting with learners to facilitate understanding also perceive learning as a constructing knowledge by learners based on their prior experiences (Koballa et al., 2000). Further, these teachers consider teaching as transforming students' understanding and learning as understanding in a new way. Therefore, they espouse teaching strategies that facilitate students to develop new understanding and see knowledge in new ways (Bahcivan and Kapucu, 2014). This literature substantiates the close association between beliefs about teaching and learning.

However, the association is not automatic considering that a small proportion of participants may exhibit inconsistent beliefs about teaching and learning (Antoniadou and Skoumios, 2013; Koballa et al., 2000). For example, in their study Koballa and colleagues observed that a small proportion of teachers view teaching as facilitating learning through interactions, yet they perceive learning as accumulating and storing knowledge for later reproduction. Cheng et al. (2009) examined the relationship between beliefs about knowledge and teaching. Researchers found that teacher candidates who hold sophisticated beliefs about knowledge as tentative, changing and personally constructed based on reasoning and justification also espoused constructivists' beliefs about teaching as facilitating students develop new understanding based on prior experiences. Four teachers however espoused inconsistent beliefs. They believe students should discover knowledge by themselves, yet they focused on transmitting textbook knowledge.

Lastly, a significant body of research shows congruency between beliefs about knowledge, teaching and learning (Bryan, 2012; Glackin, 2016; Otting et al., 2010; Tsai, 2002). Using a factor analysis Otting et al. (2010) demonstrated a structural relationship between beliefs about knowledge, teaching and learning. Most cited however is Tsai (2002) who found close congruence between beliefs about science knowledge, teaching and learning. Tsai established that teachers who view science as a representation of absolute truths perceive teaching science as transferring such knowledge to students. Consistently, they described learning science as acquiring and reproducing knowledge. For them, knowledge is located external to the learner thus; teaching must involve transmitting such knowledge to students who learn through memorisation and drilling (Sahin et al., 2016). They attribute knowledge to experts thus teaching should involve delivery, and learning should involve receiving and accumulating knowledge (Otting et al., 2010).

Similarly, studies show that ‘sophisticated beliefs’ about knowledge are closely aligned to ‘learner-centred beliefs’ about teaching and ‘constructive beliefs’ about learning science (Bryan, 2012; Tsai, 2002). These teachers believe scientific knowledge is invented through the conventions and ways of thinking agreed upon by scientists. Consistently, they believe teachers could assist students to learn through constructing personal knowledge and understanding (Tsai, 2002). In this case, teaching involves helping students connect concepts they learn in class with their experiences.

Overall, literature suggests that naïve beliefs about knowledge is aligned with both teacher-centred beliefs about teaching and cumulative beliefs about learning science (Sahin et al., 2016). Likewise, sophisticated beliefs about science knowledge are connected to learner-centred beliefs about teaching and constructive beliefs about learning. Tsai (2002) described these closely aligned beliefs as nested epistemologies. Indeed, Otting et al. suggested a possible causal relationship between beliefs about knowledge, teaching and learning. According to these researchers, beliefs about knowledge (epistemological beliefs) may influence beliefs about teaching and learning (pedagogical beliefs) which subsequently influences beliefs about knowledge via feedback loops.

Some studies however reported inconsistency between teacher beliefs about science, teaching and learning (Antoniadou and Skoumios, 2013; Bryan, 2012; Boulton-Lewis et al., 2001; Koballa et al., 2000). One reason for inconsistency between beliefs is that an individual might be in a transitionary stage of changing their beliefs (Cheng et al., 2009). Teachers could be in a state of cognitive disequilibrium during which they may hold contradictory beliefs. They could be struggling with the discrepancy between their pre-existing beliefs and current beliefs. In what follows I discuss how beliefs influence practice.

3.7 Teacher beliefs and practices: Interplay

In sections 3.5.1-3, I discussed the relationship between each beliefs category and the actual classroom practices of teachers. I showed how teachers' beliefs about scientific knowledge relates with their classroom practices. Likewise, I described the influence of teachers' beliefs about teaching and learning on the classroom teaching practices. This section focuses on the overall relationship between beliefs and practices.

In an extensive review, Kagan (1992) established that teachers' beliefs reflect the actual nature of the classroom teaching practices. Subsequent reviews (Bryan, 2012; Fang, 1996; Kember, 1997) confirmed this close relationship between beliefs and practice. Fang for example, showed that beliefs and values about teaching, learning, subject matter and learners held by teachers influence pedagogical choices and practices. Likewise, Kember (1997) concluded that teachers' beliefs determine the teaching strategies adopted, learning task set and assessment demands made. These in turn determine students' learning outcomes. In short, teachers teach consistent with their beliefs (Fang, 1996).

Recent research (see Glackin, 2016; Kang, 2008; Kang and Wallace, 2005; Levitt, 2002; Mansour, 2013) confirms the relationship between science teachers' beliefs and their practices as highlighted under each belief category (section 3.5.1-3). Generally, naïve beliefs about science knowledge, teacher-centred beliefs about teaching and cumulative beliefs about learning science are closely aligned with traditional teacher-centred teaching practices (Bryan, 2012; Kang and Wallace, 2005; Mansour, 2013). Equally, sophisticated beliefs about science, learner-centred beliefs about teaching and constructive beliefs about learning science are associated with learner-centred constructivists teaching practices (Glackin, 2016; Kang and Wallace, 2005; Mansour, 2013). Researchers often report mixed practices among teachers holding constructivists beliefs (Bryan, 2012; Kang, 2008; Mansour, 2013).

Mansour (2013) for example, reported that science teachers who viewed science knowledge as discrete absolute facts (naïve beliefs) consistently viewed teaching as transmission of knowledge to learners (teacher-centred beliefs) and learning as passive accumulation of knowledge (cumulative beliefs). In keeping with their beliefs, these teachers had transmissive teaching strategies such as lecturing, recitation and class control dominate their lessons.

Likewise, Kang and Wallace (2005) observed that teachers' beliefs were clearly reflected in their classroom practice. They found that some of the teachers in their study viewed science as a body of facts, teaching as transmitting these facts and learning as receiving and storing facts. Consistent with their beliefs, these teachers taught through lectures and demonstrations that effectively served to deliver factual knowledge. Further, they emphasised students to listen attentively to grasp concepts and answer teacher questions to display the knowledge they acquired.

Equally, teachers who view knowledge as relative, changing and constructed consistently view teaching as facilitating and creating learning environment for students to make meaning (Mansour, 2013). These teachers employ inquiry approaches in teaching science. They engage students in investigating real-world questions and facilitate knowledge discovery. Their lessons are characterised by enquiry processes including hypothesizing, predicting and deducing (Mansour, 2013). Together, these studies clearly suggest that science teachers' beliefs relate with their teaching practices.

Although the relationship between teacher beliefs and practice is well established, small body of research found complexity in the relationship between teachers' beliefs and pedagogical practices (Fang, 1996; Kang, 2008; Tsai, 2002; Waters-Adams, 2006). The association between underlying beliefs and the observable teaching act is not automatic, because teachers holding one set of beliefs such as learner-centred beliefs at times may still have to employ teaching strategies that appear inconsistent with their beliefs (Kember, 1997). This raises a question whether we could dichotomise teacher beliefs and eventually their practices into teacher-centred or learner-centred categories. Indeed, the literature concurs with Alexander (2008) who argued that in all teaching there is often a pedagogical pelleting in which teachers espouse and draw on both teacher and learner-centred strategies. Thus, teachers' beliefs may be taken as a continuum of tendencies in which some teachers may be predominantly either teacher-centred or learner-centred.

The inconsistency between teacher beliefs and practices have been demonstrated in recent research (*see* Kang, 2008; Kang and Wallace, 2005; Mansour, 2013). In a study by Mansour (2013), some participants believed students variably construct science knowledge, thus for them, teaching should focus on facilitating students understanding based on their prior experiences. Inconsistent with their beliefs, these teachers focused on passing students in the exams. They trained students on how to answer exams and provided them with model answers (Mansour, 2013). Bryan

(2012) reported similar inconsistencies between beliefs and practices in his review of research on science teacher beliefs.

The inconsistencies between the beliefs that teachers profess outside and their classroom behaviours can be caused by contextual conditions that mediate the translation of beliefs into practice (Bryan, 2012; Fang, 1996; Hutner and Markman, 2016; Mansour, 2009). Contextual factors such as peer pressure, bureaucratic demands, students' cultures, and resource-constrained large classes powerfully affect how teachers enact their beliefs (Abd-El-Khalick and Lederman, 2000; Kang, 2008; Mansour, 2013). Such classroom complexities often create dilemmas.

For example, teachers often face competing demands such as promoting students' interests and creativity or covering the prescribed subject content. To strike a balance between these competing demands, teachers have to adapt their teaching to the contextual complexities (Kang, 2008). Thus, teachers often construct their own pedagogy in ways that fit the social and material context in which they teach. Kang described this as a formation of constructively ambiguous working identity, in which teachers holding advanced views about teaching employ transmissive approaches aligned with naive beliefs to circumvent difficult classroom conditions such as inactive students, content standards and large class sizes. Whether constructivist or traditional, teachers mostly enact beliefs in practice when there is a minimal interference from the context (Mansour, 2013). Expounding on this, Mansour argued that how teachers enact their beliefs in practice is shaped by what they consider feasible and appropriate in their context, the goals they aim to achieve and the knowledge they bring into teaching context. Considering the feasibility and appropriateness of beliefs to contexts, evidence suggests that traditional beliefs are often enacted with a higher degree of fidelity than constructivist beliefs (Kang, 2008; Kang and Wallace, 2005; Mansour, 2013).

Teachers often feel confident to deliver factual knowledge for students to unproblematically memorise and unambiguously recall when answering objective test items used in the exams (Kang and Wallace, 2005). Conversely, negotiating the knowledge to promote personal meaning making and assessing such knowledge which is uniquely personal is challenging to most teachers. Therefore, such constructivists' principles are not always reflected in teachers' practices (Kang and Wallace, 2005).

Further, beliefs supportive of traditional teacher-centred teaching are often easier to enact because these are congruent with contextual conditions. For example, transmissive teaching strategies are effective for delivering prescribed subject content in school contexts where accountability structures prioritise syllabus coverage. Such conventional approaches are preferable to teachers teaching in the resource constrained overcrowded classrooms where bureaucratic system demands high scores in the public exams assessing students' knowledge of content. Conversely, much of these contextual conditions often militate against the use of learner-centred constructivist approaches (Mansour, 2013).

Drawing on Rokeach (1968), some researchers attempted to explain belief-practice interplay based on the core periphery dimension, beliefs connectedness and commitment (Haney and McArthur, 2002; Hutner and Markman, 2016; Kang, 2008; Wallace, 2014). Wallace (2014) for example, proposed that the innovative ideas about teaching and learning that teachers learn during the teacher education may initially appeal to them. However, teachers often hold these ideals peripherally compared to the core teaching beliefs they acquired through apprenticeship of observation (Lortie, 2002). Thus, teachers often temporarily show behaviours aligned with the beliefs advocated during teacher education simply because they are trying out new teaching ideas. Alternatively, they display interlude belief-practice consistency and regress back to the practices aligned with their core beliefs (Akyeampong et al., 2006).

A study by Kang (2008) found that, teachers displayed teaching strategies aligned with constructivists' epistemology only because they were eager to try out such strategies, though they did not necessarily believe in them. Over time, these teachers regressed back to the teaching practices aligned with their core beliefs. This generally makes it difficult to infer teachers' practices from their beliefs because teachers may exhibit similar practices for a very different set of reasons (Fang, 1996; Wallace, 2014).

Likewise, Haney and McArthur (2002) found teachers holding both core and peripheral beliefs. As their core constructivists' beliefs, teachers advocated encouraging students to interact and construct scientific knowledge. Researchers argued that teachers enacted and taught consistent with their beliefs because such beliefs were core to them. Conversely, teachers advocated for teaching that involve students in selecting content and learning strategies. However, such beliefs were peripheral, thus teachers rarely enacted them during the actual teaching. This suggests that peripheral beliefs are often inconsistent with practice. Teachers enact core beliefs with greater consistency because such beliefs are more connected and teachers have often used them in the past cognitive processes (Hutner and Markman, 2016).

Together, these studies illustrate that teachers' beliefs about knowledge, teaching and learning are related to and influence their classroom practices (Haney and McArthur, 2002; Hutner and Markman, 2016). However, espousing beliefs that support certain practice is only necessary but not sufficient for teaching consistent to that belief. This is because structural conditions mediate the translation of beliefs into relevant practice in complex ways. Since beliefs associated with traditional teacher-centred teaching are often more feasible under the existing contextual constrains, teachers often enact such beliefs with high degree of consistency. Thus, traditional beliefs (naïve beliefs, teacher-centred beliefs and cumulative beliefs) are often congruent with practices than constructivists beliefs. Depending on the beliefs they hold, teachers may teach using approaches characterised as either teacher-centred, learner-centred or both. I discuss this next.

3.8 Science teachers' pedagogical practices

Researchers often label teachers' pedagogical practices using contrasting terms of teacher-centred and learner-centred pedagogies (Brophy, 2002; Tabulawa, 2013; Westwood, 2008). In this section, I discuss how researchers have conceptualised 'pedagogy' before moving on to describe the principles and practices that symbolise teacher-centred and learner-centred pedagogies.

3.8.1 Conceptualising pedagogy

Pedagogy in education has been conceptualised with a shifting focus over time. Earlier conceptions focused on personal teaching style, often described using polarized terms such as authoritarian versus democratic and integrative versus dominative teaching with the purpose of identifying bad or good approaches (Watkins and Mortimore, 1999). Subscribers of this view defined pedagogy in terms of methods and styles of teaching a teacher chose. Later, conception of pedagogy expanded to encompass organizational and contextual factors such as subject organisation and resources that influence pedagogical practices.

When the constructivists' conception of learning as an active construction of knowledge based on prior experiences become popular, the meaning of pedagogy expanded to highlight the active role of learners in teaching and learning process. Building on constructivists' view, Watkins and Mortimore (1999) defined pedagogy as any conscious activity a teacher design to enhance learning in learners. Alexander (2001) reviewed this earlier notion for equating pedagogy with an observable act of teaching, thereby placing it outside the associated theories, beliefs, policies, and controversies that shapes pedagogy. For Alexander (2008) therefore:

> Pedagogy is the observable act of teaching together with its attendant discourse of educational theories, values, evidence and justifications. It is what one needs to know, and the skills one needs to command, in order to make and justify the many different kinds of decisions of which teaching is constituted (p. 47).

Inherent in Alexander's view of pedagogy are two critical aspects; pedagogy as the observable act of teaching, and pedagogy as thinking and ideas including theories, beliefs, values and evidence that informs and justifies the act of teaching. Alexander further argued that the discourses about teaching, learning, learners and knowledge shaped and modified by contexts, culture and policy are at the core of pedagogy. Such discourses I argue, encompasses teachers' beliefs about knowledge, teaching and learning.

In the context of school curriculum in Tanzania, pedagogy is equated with the act of teaching often expressed in terms of teaching methods and learning activities (MoEVT, 2013). This makes pedagogy a value-free technical undertaking

(Tabulawa, 2013). Consequently, attempts[2] to improve pedagogical practices are often narrowed to technical solutions largely focused at equipping teachers with skills and knowledge on how to organise small groups and use teaching and learning materials. This is often accomplished through workshops, seminars and similar forms of ad hoc professional development programmes. This technicist approach to teaching reform often leaves teachers with a narrow understanding of the principles of learner-centred pedagogy and how this could be applied in varied classroom contexts (Akyeampong, 2017). I argue that this simplistic view of pedagogy in the Tanzania curriculum context downplays the role of deep-rooted personal, cultural, and social subjectivities (including beliefs) of teachers that informs and shapes pedagogy.

Instructional approaches are often categorised into teacher-centred and learner-centred pedagogies considering the magnitude of control that teachers or students exercise during teaching and learning. I discuss these next.

3.8.2 Teacher-centred pedagogy

Researchers variously label teacher-centred pedagogy as traditional, didactic, whole-class, expository and transmissive teaching (Brophy, 2002; Guthrie, 2011; Magnusson et al., 1999). In science teaching, this approach firmly places a teacher in the role of transmitting scientific facts and questioning students, holding them accountable for knowing facts (Magnusson et al., 1999).

As a knowledge repository, a teacher has a dominant hierarchical role, while students are generally passive, despite a limited teacher-student and student-

[2] Typically, in Tanzania and indeed in many sub-Saharan African countries, these attempts endeavoured to bring a paradigm shift from the dominant teacher-centred approaches to learner-centred pedagogy including in science teaching.

student interactions permitted under teachers' control (Guthrie, 2011). The emphasis is on the rote memorization of a body of science knowledge presented in textbooks (Brophy, 2002). Further, the routinized whole-class processing of strongly framed syllabi and textbooks in which every student works on the same task at the same pace and time symbolises teacher-centred pedagogy (Alexander, 2006).

Learning involves drilling, recitation, and routine repetition of facts until students internalise and can reproduce such facts on demand (Alexander, 2006). To ascertain knowledge acquisition, teachers ask closed questions to a whole class or individual students seeking to elicit single correct answers (Brophy, 2002). Teachers judge the accuracy of answers based on textbook content and they ignore incorrect answers because they often do not invite students to justify their thinking. This means, ability to recall textbook knowledge serves as an indicator of learning proficiency.

This kind of teaching practice enable teachers to remain firmly in control of the lesson events and ideas (Alexander, 2006). Teachers employ teaching methods such as lecturing, recitation, demonstration and exposition. Physically, teachers organise the classroom to facilitate unidirectional transmission of knowledge by arranging desks in rows, all facing the front where a teacher stand and speak (Alexander, 2001; Tabulawa, 2013).

Objectivists' view of knowledge as given, propositional and unchanging thus transmittable from authoritative sources (teacher or textbook) to learners informs teacher-centred teaching (Brophy, 2002). This teaching though unlikely to challenge learners cognitively or deepen their learning, largely remains the default practice across the classrooms of the world (Alexander, 2006). In Tanzania and indeed in many sub-Saharan African countries, researchers largely agree that teacher-centred teaching symbolised by rote and recitation approaches to teaching and learning continues to dominate classrooms (Akyeampong et al., 2006; Hardman, 2015; Vavrus, 2009; Vavrus and Bartlett, 2012). Stories of failure or lack of sustained success in changing the default teacher-centred pedagogy to the aspired learner-centred approach continues to feature research on classroom teaching in sub-Saharan Africa (Akyeampong, 2017; Guthrie, 2016; Hardman, 2015). Literature often contrasts teacher-centred pedagogy with learner-centred pedagogy, which I describe next.

3.8.3 Learner-centred pedagogy

Researchers variously label learner-centred pedagogy as participatory methods, child-centred pedagogy, activity-based methods, and inquiry-based methods (Tabulawa, 2013). In science education literature, it is termed inquiry learning, problem-based learning, reform-based pedagogy, reformed pedagogy, and constructivist based-pedagogy (Luehmann, 2007). These are strands of progressive pedagogies, which embrace a wide range of practices thus conceptualised differently (Alexander, 2008; Schweisfurth, 2015).

Weimer (2002) defined learner-centred pedagogy as an approach to teaching and learning in which the learner and learning are central to the instructional decisions and processes. The focus is on what, how and under what condition the learner is learning. Further, learners' active construction of their knowledge based on prior experiences as opposed to mere recipients symbolise learner-centred teaching. This is a move away from the traditional power imbalance between the teacher and the learner where learners assume active responsibilities for their own learning (Mtika and Gates, 2010).

Learner-centred pedagogy is founded on constructivists learning theory, which emphasises the view that individuals actively construct knowledge and understanding basing on their pre-existing experiences and thought (Bruner, 1996; Taber, 2014). In science teaching context, learner-centred pedagogy involves learners' engagement in inquiry and problem solving. It may involve posing questions, exploring possible ways for investigations, gathering evidence, analysing and thinking critically about the evidence and communicating arguments (Taber, 2014; Westwood, 2008). Teachers monitor discussions and group activities and intervene when required to redirect and address misconceptions. They also ask questions, seek, or provide clarification and help to identify areas of consensus and disagreement (Brophy, 2002). Learner-centred teaching methods may include small-group activities, debates, Buzz groups, discovery learning, inquiry, and problem or project-based learning (Westwood, 2008). In what follows I discuss the critical aspects of learner-centred pedagogy.

3.8.4 Contested aspects of learner-centred pedagogy

Although learner-centred pedagogy has continued to attract education policy reformers as a panacea to the problems of underachievement, school dropout and school leavers with no employable skills, there is a growing scepticism about the superiority of this approach (Guthrie, 2011; Kirschner et al., 2006). Consequently, there has been attempts to identify critical elements of learner-centred teaching and learning which I discuss next.

Contextual (in)compatibility

Literature shows that learner-centred pedagogy has never been fully implemented even in the contexts where it has been in place for considerably longer period than in sub-Saharan African (Kirschner et al., 2006). Studies demonstrate widespread pedagogical pelleting involving both teacher-centred and learner-centred practices depending on the classroom contexts (Barrett, 2007; Vavrus, 2009; Vavrus and Bartlett, 2012). Indeed, teachers make ‘contextually constrained pedagogical choices’ by adopting some aspects of learner-centred pedagogy such as group activities and interactions but not others such as involving students in deciding content and how it should be learned (Lea et al., 2003, p. 323). Two contextual constraints are worthy highlighting.

First, research in sub-Saharan Africa (including Tanzania) indicates that classroom conditions militate against the adoption of learner-centred pedagogy. Resource-constrained large classes, overloaded curriculum content, and high-stake exams that measure students’ recall of content knowledge limit the implementation of learner-centred pedagogy (Barrett, 2007; Semali and Mehta, 2012; Vavrus, 2009; Vavrus and Bartlett, 2012).

Vavrus and Bartlett for example, argued that the principles that underlie learner-centred pedagogy assume certain material conditions, which are non-existent in most sub-Saharan Africa. For them, learner-centred pedagogy was ‘developed in specific material contexts of generally abundant textbooks, laboratories, and access to ICT’s’ (p. 640). Policy makers under the influence of international aid agencies uncritically exported learner-centred education to the resource constrained classrooms of sub-Saharan Africa. This makes learner-centred pedagogy incompatible with the context (Vavrus and Bartlett, 2012).

Second, the relevance of learner-centred approaches to classroom contexts in developing countries has been questioned from socio-cultural perspectives (Akyeampong et al., 2006; Guthrie, 2016; Guthrie et al., 2015). As explained in section 3.3.1, traditional African society has a unified epistemology in which deities reveal knowledge in a prefabricated form to elders who subsequently pass it to children (Kresse, 2009). Therefore, the society assumes that those with longer life experiences have accumulated large stock of knowledge, which gives the society a hierarchical structure with elders being authoritative over children.

Consequently, elders and children are not socialised to negotiating knowledge and truths as envisioned in the curriculum, instead these are given and received. All these deep-rooted cultural beliefs about knowledge and teaching could be incompatible with the principles and practice of learner-centred pedagogy (Tabulawa, 2013; Guthrie, 2011). Instead, teacher-centred pedagogy appears logically coherent with the revelatory epistemologies and cultural modes of thinking that dominate African societies (Guthrie et al., 2015). How?

Writing about indigenous education in Tanzania, Mushi (2009) argued that traditional education has a body of knowledge that constitutes cultural norms, values and shared ways of life inherited from the past generations. This body of knowledge is given, fixed and embodied in elders and special teachers. It was compulsory for young members of the tribe to acquire this body of knowledge from the ethnic knowledge authorities (elders and special teachers) who taught by transmitting it. As knowledge authorities, traditional teachers and elders were at the centre of the teaching and learning process, making key decisions regarding when, what and how young people should learn. These tenets of traditional education look far more congruent with teacher-centred pedagogy compared to learner-centred pedagogy.

Further, the assumptions underlying learner-centred pedagogy including the principle that learners should construct knowledge based on prior experiences through active participation conflict with the value system of African societies. The intellectual enquiry and freedom to question teachers and adults seem to conflict with cultural values that symbolise revelatory epistemologies and adults' authority over children. Indeed, Mushi (2009) argued that elders did not accept critique or changes of traditional knowledge; instead, docile acceptance of it was valued while intellectual endeavours and abstract reasoning beyond this was deemphasised and discouraged. All these renders learner-centred pedagogy culturally incompatible (Tabulawa, 2013).

Considering the cultural modes into which teachers and students were socialised, they could be holding beliefs and assumptions about teaching and learning that may conflict with the underlying principles of learner-centred teaching. As one of its basic tenets for example, learner-centred teaching requires shift in power and responsibility from teachers to students (Mtika and Gates, 2010). In this context, teachers may feel loss of authority over knowledge as well as power and control over students. This could conflict with their cultural modes of thoughts.

Further, research shows that students' behaviours could have partly reinforced the resilience of teacher-centred practices particularly in the African classrooms. In Boswana, Tabulawa (2013) found students overtly and covertly seeking to keep teachers in information giving role thereby limiting teachers' attempts to engage them in learning. For this reason, the widely spread teacher-centred teaching is said to be partly co-constructed and propagated jointly between teachers and students (Guthrie et al., 2015).

Guthrie (2011) therefore concluded that teaching is a culture-bound practice and so the attempts to improve it should consider cultural orientation of the society. However, this has not been the case because the attempts to introduce learner-centred teaching often ignored the socio-cultural values under which schools, teachers and learners in sub-Saharan Africa operate (Vavrus and Bartlett, 2012). Consequently, teachers and students have rationally resisted learner-centred innovation on the grounds of their cultural values and experiential understanding of the school contexts.

Content or skills, knowledge or process: False dichotomies

Advocates of learner-centred pedagogy have been criticised for creating a false dichotomy between subject matter knowledge and higher order skills such as critical thinking, creativity, problem solving, and inquiry skills (Kirschner et al., 2006). This approach has been questioned for shifting emphasis from ‘learning discipline as a body of knowledge to exclusive emphasis on learning a discipline by experiencing the process and procedures of the discipline’ (p. 78).

According to Kirschner et al. this shift in focus is associated with extensive use of practical and project work through discovery and inquiry methods and rejection of teaching subject knowledge. Kirschner et al., consider this approach flawed for it does not distinguish between learning a discipline and practising a discipline. The consequence of over emphasis on the so-called 21st century skills is that students graduate school with little knowledge of the disciplines.

Further, there is a growing consensus that students cannot learn higher order skills without first memorising a good deal of factual knowledge. Young (2014) for example, argued that, students who are conversant with a given subject can critically think about it but not about a subject, they do not know. Thus, a widespread conviction to inquiry methods as a means to promote higher intellectual skills without subject knowledge is unproven conjecture (Guthrie, 2011).

Kirschner et al. (2006) and others who have advanced similar arguments about learner-centred methods might have overlooked key facts and premises as highlighted by Hmelo-Silver et al. (2007), Kuhn (2007) and Schmidt et al. (2007). First, the need for change in the focus of educational goals is not simply a constructivists' agenda for teaching but a wider public demand for reforms in education. Education ministries and professional associations including subject expert bodies are all pleading for the emphasis not only on disciplinary content but also on the disciplinary ways of knowing and investigative strategies (Hmelo-Silver et al., 2007; Kuhn, 2007).

Second, Hmelo-Silver et al. (2007) argued that learner-centred approaches including problem-based learning and inquiry learning are not content void as critics claim. The emphasis is not only on learning higher order skills but also on the deeper and meaningful acquisition of content knowledge rather than simple memorisation. Learner-centred teaching involves some forms of direct instruction as one of the repertoire of strategies used to facilitate knowledge construction. Direct instruction in the form of mini-lectures, are used to provide content students need to know on just-in-time basis (Hmelo-Silver et al., 2007).

Lastly, the supporters of learner-centred pedagogy do not advocate replacing subject content with disciplinary practices, they recognise both as core learning goals. According to Hmelo-Silver et al. examples of effective inquiry-based teaching environments supporting both learning content and disciplinary practices exists. Given that it is becoming increasingly impossible to predict the kind of knowledge people will require to prosper in the 21st century, it is imperative to equip the new generation not simply with content knowledge but with knowledge creation skills that will enable them to flexibly adapt to the continually vibrant and fickle world (Kuhn, 2007). In short, proponents of learner-centred teaching do not exclusively reject teaching content but contest the sole focus on teaching it at the expense of transferable skills such as problem solving, inquiry, critical thinking and learning to learn that may be crucial for 21st century survival.

Cognitive burden of minimal guidance

Supporters of learner-centred teaching have been criticised for a lack of attention to the nature of working memory and long-term memory and the interaction between them (Kirschner et al., 2006). Drawing on the evidence from research on cognitive architecture, Kirschner et al. advanced three key arguments.

First, they claimed that experts are far better at problem solving than novices because the former possess extensive knowledge in their long-term memory which they use to solve problems. From this perspective, both simple acts such overtaking vehicles on the road to complex ones such as solving math problems requires individuals to draw on information stored in the long-term memory. Considering this evidence, teachers should give students a subject knowledge to enhance their problem-solving skills in each domain.

Second, researchers claimed that encouraging learners to freely explore materials to construct knowledge instead of directly giving them knowledge is detrimental to learning for such approach creates a heavy cognitive load on the working memory of a learner. Kirschner et al. argued that when a learner is using working memory to search information (as in inquiry learning); such memory is unavailable hence it does not facilitate transfer and accumulation of knowledge into long-term memory. Consequently, learners do not acquire the content they need to become skilled problem solvers. Therefore, unguided or partially guided instructions often advocated by constructivists may result into poor learning.

Most of these claims have been demonstrated defective (Hmelo-Silver et al., 2007; Kuhn, 2007). First, the assumption that when learners are required to construct knowledge as often advocated by constructivists does not automatically mean learning with minimal or without guidance (Mayer, 2004). Second, most learner-centred instructional approaches are not minimally guided as cognitive load theorist claim (Hmelo-Silver et al., 2007).

Overall, the relevance of learner-centred pedagogy to developing countries context has prompted much debate among researchers (Barrett, 2007; Guthrie et al., 2015; Kirschner et al., 2006; Vavrus and Bartlett, 2012). However, this does not seem to obstruct the popularity of learner-centred pedagogies to policy makers particularly in sub-Saharan Africa. In Tanzania for example, a newly launched Education and Training Policy clearly appeals to learner-centred pedagogy as an approach to teaching and learning in schools (MoEVT, 2014). In what follows I describe frameworks that I used to analyse teaching.

3.9. Analysing teaching practices: Action-based framework

While others dichotomise teacher–centred and learner-centred pedagogies (Tabulawa, 2013), a growing body of literature advocate viewing the two as lying on the continuum (Alexander, 2006; Barrett, 2007; Guthrie, 2011). Alexander (2006) for example, advocate for the replacement of pedagogical polarisation with the notion of *repertoire* (emphasis original) of pedagogical options necessary for teachers to teach successfully in the classrooms with diverse learners, conditions, and goals.

Basing on Bernstein's pedagogic modes of performance (teacher-centred) and competence (learner-centred), Barrett (2007) also argued that learner-centred and teacher-centred pedagogies are non-contradictory if their co-existence is accepted. Thus, the proponents of continuum thesis argue that optimal teaching inevitably involves blending both teacher-centred techniques such as rote memorization and recitation as well as learner-centred techniques such as discussion and dialogue (Alexander, 2006; Guthrie, 2011).

However, the continuum view can be questioned considering Akyeampong et al. (2006) who observed that even if teachers may initially embrace learner-centred pedagogy, such practices are often short-lived as teachers would ultimately recidivate to the default teacher-centred teaching. This means there are contexts where teaching could be predominantly teacher-centred, making the dichotomy inevitable. Holding on to the polarized view therefore, Tabulawa (2013) argued that the two orientations are founded on the opposed assumptions about nature of knowledge, teaching and learning thus intrinsically incompatible.

Teacher-centred pedagogy is deeply rooted in objectivists' epistemology in which knowledge is viewed as detached from human subjectivity thus certain, absolute, fixed, made of isolated bits and handed down by authority (Alexander, 2001; Schommer, 1990). Conversely, learner-centred pedagogy is rooted in social constructivist epistemology in which knowledge is viewed as tentative, evolving and relative; made of socially constructed interrelated concepts (Alexander, 2001; Schommer, 1990). These differing assumptions about the nature of knowledge, teaching and learning translates into teaching practices, teacher-student interactions and classroom organization that are distinctively different (Tabulawa, 2013).

Considering these debates, researchers have drawn on different frameworks to analyse teaching. I highlight two most common; *action-based framework* by Robin

Alexander and *performance and competence pedagogic models* by Basil Bernstein (Alexander, 2001; Bernstein, 2000, my emphasis).

3.9.1 Bernstein's pedagogic models

Basil Bernstein (2000) framed teaching into competence and performance models. Competence model is aligned with learner-centred pedagogy and performance model is aligned with teacher-centred pedagogy (Barrett, 2007; Sabella and Crossouard, 2017). Bernstein contrasts competence with performance pedagogical practices considering discourse, teaching organisation and learning outcomes.

Under performance model, a teacher dictates the content and the sequence and pace at which learners learn. The lesson structure is often firmly framed with clearly marked and regulated classroom organisation, routines, and rules. Thus, instructional practices often encourage uniform and collective behaviour pattern and standardised outcomes. This makes personalised and self-regulated learning by students less favourable (Bernstein, 2000).

Under the competence model, students have a great deal of control over what, how and at what pace they should learn. The lesson structure is weakly framed with implicit, less regulated and flexible classroom organisation, which is often based on learners' needs. Therefore, teachers facilitate learning and learners self-regulate and assume responsibility for their learning. Learning outcomes are personalised and varied thus, the criteria for evaluation are implicit and diffused (Bernstein, 2000).

Although Bernstein's model provides a useful framework for understanding teaching practices, it may be limited when analysing diverse pedagogical practices that may fall beyond the performance and competence models or their amalgam. To account for the diverse pedagogical practices that could be found in the study schools, I adopted action-based framework for analysing teaching, which I describe next.

3.9.2 Action-based framework for analysing teaching

Teachers' beliefs and practices are influenced by cultural values on how learners relate to each other and to teachers beyond the relationships amplified in the pedagogical dichotomies (Alexander, 2008). Further, there are multiple views on what teaching is all about across cultures that transcend beyond teacher-centred and learner-centred dichotomies. This provides the rationale for extending a range of pedagogical orientations beyond the dominant dichotomies. Thus, to break away from polarised models of teaching, Alexander proposed an *action-based framework for analysing teaching* (2001, p. 325, my emphasis).

This consists of three broad analytic concepts of *frame, form,* and *act* (emphasis original). Frame stands for the immediate context within which the act of teaching is set. Teaching context constitutes elements such as space, student organization, time, curriculum and habits. Classrooms, laboratories, and individual students' desks makes up space. Within this space, students' desks may be organised in rows, u-shaped, theatre, herringbone, hollow-square, group tables, horseshoe and stadium-like arrangement. In other words, space is the way classroom is disposed, organized, and resourced while students may be organised in whole class, small group and individual. Further, curriculum may be strongly framed into specific subjects to be covered in a specified time, which may also be regular and fixed or irregular and flexible. According to Alexander, habits constitute routines, rules and rituals that guide teacher-students' interactions during the lesson.

The core acts of teaching encompass tasks, activities, interactions, and judgements. Tasks entails the type of learning a teacher intends students to achieve including the knowledge they acquire and cognitive development they attain. Task may for example seek to foster learners to acquire *metacognitive* knowledge and develop *creativity* (Krathwohl, 2001, emphasis added). To carry out the task, students must perform an activity, which is a means by which students accomplish task. Typical activities may range from simple listening and watching to group discussions, debates, and collaborative inquiry. When performing learning activities students and teachers interact in various patterns including teacher with whole class, teacher with individual student, teacher with group, individual students with whole class (Alexander, 2001).

Teaching has a structure and form, which manifests in a lesson. Time, space and chosen forms of students' organisation frame and govern lesson and its' constituent acts of teaching including tasks, activities, interactions and judgements. An action-based framework is shown in figure 3.2.

Frame	Form	Act
Space		Task
Student organization		Activity
Time	Lesson	
Curriculum		Interaction
Routine, rules and ritual		Judgement

Fig. 3.2: An action-based framework for analysing teaching (Alexander, 2001 p. 325).

The connection between these analytic concepts is that the core acts of teaching (task, activity, interaction and judgement) are framed by classroom organization (spaces, resources and people), time and curriculum and by classroom routines, rules and rituals. These are given form in the lesson or teaching session (Alexander, 2001).

Alexander argued that when researchers apply this framework in analysing teaching practices, they might end up with six instead of two dichotomous pedagogic modes. Based on *Five Cultures* study that analysed and compared teaching in five different countries, Alexander and colleagues observed six versions of teaching (Alexander, 2001). These versions of teaching which I describe next constitute a continuum of tendencies than a set of discrete descriptors.

Teaching as transmission is a basic teaching model characterised by teachers imparting knowledge as given, structured and fixed into permanent disciplines. The teacher dominates teaching and learning process and learners mainly remain passive receivers of knowledge. Emphasis is on the rote memorisation and recitation of facts and principles (Alexander, 2008).

Teaching as initiation is characterised by exposition of students to disciplinary knowledge. A teacher strives to enable students to understand knowledge rather than passively memorising it (Alexander, 2008). However, the knowledge is still viewed as facts and principles to be acquired and stored. Teachers permit some classroom interaction through closed-ended questions and recall of answers (Guthrie, 2011).

Teaching as negotiation is characterised by the rejection of traditional teacher dominance of a learner, treating them as joint enquirers instead. Further, teachers and learners view knowledge as more subjective, changing, and constructed rather than objective, fixed and handed by authority. Teachers employ interactive teaching methods to empower learners to take active control of their learning (Alexander, 2008).

Teaching as facilitation is characterised by teachers acknowledging individual learners' unique ways of thinking and making sense of the world. Therefore, teachers facilitate personal meaning and construction of knowledge rather than directly dictating knowledge (Alexander, 2008). The assumption is that learners learn at different paces and therefore, they should not be pushed because they will ultimately learn when they are ready. Learners take active role in their learning and teaching is adapted to their needs.

Each version of teaching carries with it certain assumptions about knowledge, teaching and learning. Such assumptions include ideas, beliefs and understandings about subject matter, teaching and learning held by teachers. At the core of Alexander's view of pedagogy is that such assumptions (discourses) influence the act of teaching. Based on the key assumptions and the extent to which a teacher or a learner controls the teaching and learning process, the six versions of teaching can be placed in a continuum of teaching practices. In the order of diminishing teacher control, teaching as transmission forms the basic level and teaching as acceleration and technology is the advanced level.

Alexander's action-based framework allows an analysis of diverse range of pedagogic practices that may fall within the continuum of six versions of teaching. I adopted this framework particularly his concepts of frame, form, and act of teaching to analyse science teachers' practices in Tanzania. I linked the selected elements of teaching such as tasks, activities, and interactions to teachers' beliefs about science knowledge, teaching and learning. The aim being to establish consistencies and inconsistencies between the two.

3.10 Chapter summary

Teachers whether beginners or experienced consciously or unconsciously hold implicit ideas and assumptions about subject content, teaching, learners and learning. Researchers described these variously, though the terms beliefs and conceptions are common and interchangeably used. I adopted 'beliefs' following Kagan (1992). Beliefs are part of human cognitive schema upon which individuals draw during the cognitive process such as thinking, making decisions and choices.

In the context of teaching reforms, beliefs about subject matter, teaching and learning are the most salient.

Considering the magnitude of sophistication, teachers' beliefs about knowledge can be categorised into naïve/dualist/realist beliefs and sophisticated/informed/relativists beliefs. I will use 'naïve' and 'sophisticated' beliefs following Schommer (1990). Science teachers holding sophisticated beliefs about knowledge are more receptive to learner-centred pedagogy compared to those holding naïve beliefs.

Teachers' beliefs about teaching science are clustered into beliefs aligned to 'learner-centred teaching' and beliefs aligned to 'teacher-centred teaching'. Likewise, teacher beliefs about learning are categorised into beliefs aligned to 'cumulative views' and beliefs aligned to 'constructive views' of learning. Some scholars contest this way of framing beliefs for oversimplification, yet it remains useful for analysing and understanding teachers' beliefs.

Beliefs about science knowledge, teaching and learning are related. Tsai (2002) described related beliefs as 'nested epistemologies' (p.771). Generally, teachers holding naïve beliefs about science also hold teacher-centred beliefs about teaching and cumulative beliefs about learning. I will call this set a 'traditional beliefs' throughout the rest of the chapters. Likewise, teachers hold sophisticated beliefs about science knowledge in conjunction with learner-centred beliefs about teaching and constructive beliefs about learning. I will call this set a 'constructivists beliefs' throughout the rest of the chapters. In the next chapter, I outline my methodological approach to the study.

Chapter 4: Methodology

4.0 Introduction

Researchers have used case studies, phenomenology, grounded theory, and narrative inquiry to explore teacher beliefs (Olafson et al., 2015). Overall, the emphasis has been on the deeper understanding of teachers' thinking and the way beliefs manifest in their teaching practices. Consistent with this, I adopted a phenomenological approach. Teachers' beliefs are about personal understanding of concepts of science, teaching, and learning. These concepts carry personal meaning to the teachers. Adopting a phenomenological approach allows the researcher to access such meanings.

In this chapter, I explain the basis of my methodological approach and the methods I adopted to gather and analyse data. I provide details about the selected participants and techniques I used to generate and analyse data. Next, I discuss the way in which I related to research participants and setting, the challenges I faced and how I addressed them to ensure the production of an account of science teachers' beliefs and the relationship to their practice. To start with, I describe the ontological and epistemological underpinnings of the study.

4.1 Ontological and epistemological assumptions

To understand the social world and how it functions, it is important to focus inquiry into the way humans act and the meanings they make of them (Bryman, 2012). This is because social actions have meanings to humans who perform them (Lincoln and Guba, 2013). When humans act, they think and reflect both consciously and unconsciously drawing upon their past experiences, current context, and future expectations.

To understand social actions, one needs to uncover the meanings or motivations behind the actions. Therefore, the task for the social science researcher is to grasp human subjective meanings and interpret their actions based on the meanings behind these actions (Bryman, 2012). The term used to denote this philosophical stance is interpretivism (Rubin and Babbie, 2011; Bryman, 2012*)*. Rubin and Babbie (2011) defined interpretivism as a research paradigm that focuses on gaining an understanding of how people feel inside, seeking to interpret individual everyday experiences, their deeper meanings and feelings and the reasons for their actions.

I adopted the interpretivist view in my study of understanding science teacher beliefs and the way these relate to their practices because it allows access to the meanings that teachers accord to science, teaching and learning. Thus, for me, my interest in understanding meanings informed the choices I made when it came to deciding the approaches and methods I should adopt in my study (see, Savin-Baden and Major, 2013). Having affirmed an interpretivist stance, I now explicate ontological and epistemological assumptions that guided the study.

Generally, I subscribe to the view that reality exists in the form of multiple subjective mental constructions based on an individual's social, historical and cultural contexts (Lincoln and Guba, 2013; Savin-Baden and Major, 2013). Therefore, to understand the reality of science teachers' beliefs about science knowledge, teaching and learning, it was important to focus on the teachers' ways of thinking. Further, given that individual science teachers have unique experiences of science teaching, there exist multiple realities of their beliefs (Laverty, 2003). These multiple realities are considered to be locally and socially constructed in the context in which teachers teach science (Laverty, 2003; Lincoln and Guba, 2013).

From an epistemological perspective, adopting an interpretivist approach means I assume that the researcher and the participants subjectively co-construct knowledge through interaction (Lincoln and Guba, 2013). In other words, how I as a researcher interact with participants plays a crucial part in how I come to understand and 'see' their world through their own eyes. In keeping with this perspective, I explored science teachers' beliefs about science, teaching and learning through conversations and interaction with the teachers. This involved deeper discussions and explorations with the teachers to arrive at mutual understanding about their beliefs.

Finally, I acknowledge that both the participants and I could hardly set aside our prior experiences, pre-understandings, and preconceptions (Creswell, 2013; Lueger and Vettori, 2014). This is because our understanding is often with presupposition thus we can hardly view the world from a purely objective stance. We always understand from within the context of our dispositions and involvement in the world (Johnson, 2000). These values are inevitably part of who we are as humans. For example, as a teacher of science for three years in the context of Tanzania secondary education, I cannot ignore the fact that my own assumptions and personal experiences played a part in how I came to understand and interpret science teachers' beliefs. I interrogated their beliefs drawing on my own knowledge and experience of teaching science to produce a shared understanding and interpretation. I present details of this in section 4.4.2. I now turn to the research strategy I adopted for my study.

4.2 Research strategy

As outlined in the foregoing section, I sought to explore the meanings science teachers ascribe to science knowledge, teaching and learning. To describe, interpret and understand these meanings, I adopted a phenomenological approach inspired by van Mannen's (1990) conception of phenomenology as a research strategy seeking to describe and interpret lived experiences[3]. In my context, these constitute the experiences of teaching science and the meanings teachers attach to their experiences.

I share the view that when individuals express their experiences they inevitably encapsulate their culturally and socially informed interpretation (Heidegger, 1962). In the context of this study, I assumed that science teachers express their beliefs about science knowledge, teaching and learning mainly in the cultural and social context in which they teach. My understanding and interpretation of teachers' beliefs also considered this cultural and social context, which I am familiar with. For example, when teachers say, 'they want me to flow' or 'it was more of swallowing', I interpreted this in the schools' social and cultural contexts in Tanzania where both I and participants studied. Meanings are better understood within the cultural and social contexts in which they are articulated (Lueger and Vettori, 2014).

4.3 Methods

4.3.1: Site selection

The research sites are secondary schools in Tanzania. As indicated in section 2.2.2, secondary schools are often categorised into community, private and government schools. These vary considering academic performance, resourcing, staff remuneration, ownership and location. Most of the community schools are in the rural areas and suburbs. The government in collaboration with the local communities established these schools from the late 1990's. Community schools generally face shortage of resources and teachers thus, underperform in the national examination compared to other categories.

[3] What teachers take for granted about teaching of science. E.g. memorising formula, writing lesson notes. Teaching involves copying lesson notes is a lived experience.

Private schools are mostly located in the cities and towns. These schools are generally well-resourced and staffed. They are moderate to high performing schools with well-paid teachers compared to community and government schools. Government schools are in both rural and urban areas. They are relatively aged, moderately resourced and staffed.

Rokeach (1968) cautioned that what people say at the ‘surface level’ may or may not portray their true beliefs because most are not conscious of their beliefs. For this reason, in-depth conversation is inevitable to get deeper into what teachers believe, intend, and do. Since I set out to understand what teachers truly believe and the way in which they reflect these in their actual teaching, it was necessary to select few schools for in-depth investigation. Further, to gain in-depth insights into the ‘real time’ impact of teachers’ beliefs on their pedagogical choices and decisions, I aimed to document teachers’ espoused beliefs, justifications for their beliefs and actions and link these during or shortly after the teaching activity. This required selecting schools that I could access day in and day out and stay with teachers for prolonged periods without disruptions due to travel between rural and urban districts. In short, understanding the belief-practice relationship demanded interviews be based on teaching tasks. To achieve this, selecting schools I could access and stay in for prolonged time was imperative. Therefore, I selected two schools from the main school categories, one urban and another suburban but both in accessible locations. These are Marera secondary school, which a community school and Getamock which is a private school.

After securing research permits from the relevant local authorities, I approached three different private schools. I described the purpose of my research to the principals of the respective schools and requested permission to invite science teachers to participate in the study. Of the three private schools approached, I gained immediate permission at Getamock, delayed access in the second school and denied permission in the third school. The principal of the third school did not provide apparent reason except he said teachers had other commitments and could not have time to participate in the study. From my experience, some private schools may be reluctant to welcome researchers to conceal their schools' practices and cultures. Marera was the only community school I approached and I was welcomed wholeheartedly.

Marera is located on the outskirts of Dar es Salaam, over 30 kilometres away from the city centre while Getamock is in the city centre. Both schools are co-education, use the same curriculum and students sit for the same national examination. The schools had similar patterns of students' achievement in the national examination results for the past five years. Despite these similarities, the schools varied considering students' population, resources, and ratios of teachers to students. I outline further details about each school in the later sections. The names of schools, teachers, and students are pseudonyms. The exact numbers of students and teachers and the actual names of the places are concealed to protect participants' identities from colleagues, neighbours, and authorities.

Getamock secondary school

This is a privately-owned school, which is part of a network of several other schools belonging to the same owner. It is a relatively small school with over 400 students split into streams of approximately 30 students depending on the grade level. Streams in first secondary education grade levels (13 and 14 years) had relatively more students compared to the streams in the later grade levels (16 and 17 years).

This was partly because students were screened basing on the results of the exam they took at the end of the year two of the four-year secondary education.

Typical of many other private schools, Getamock had set its' own benchmark score, which is far higher than the government pass mark of 30%. At Getamock, when students do not attain school benchmark score, school authorities either expelled them from school or advised them to seek places in other schools. However, education circular no. 16 of 2011 prohibits schools from setting their own benchmarks upon which they make decisions for students to repeat the same grade or dropout from the school. The circular stipulates that 'b*y this circular, I order that from now onwards, no school shall be allowed to grade-repeat, transfer, or expel a student because of failure to attain a benchmark set by a school* (Education circular no. 12 of 2011, my translation). Science streams were even smaller because less students normally opt for science subjects.

The overall ratios of teachers to students was far below the district teacher-student ratio of 1:26 and close to national teacher-student ratio of 1:20 for private schools (PMO-RALG, 2014). Teacher-student ratio was higher for science subjects thus science teachers generally taught more lessons per week compared to teachers of other subjects. On average Biology and Chemistry teachers taught slightly less while Physics teachers taught slightly higher than the standard teaching load prescribed by the Ministry of Education.

The classrooms had electricity and each student had a chair and a space in a shared table. There is one laboratory for each science subject. I observed no charts, models, drawing or posters in all the classrooms. Teachers admitted that they rarely prepare their own teaching and learning materials. They acknowledged that the school laboratories had models and charts but they rarely use them. In the Chemistry and Biology laboratories, I observed various charts ranging from charts showing human digestive and circulatory systems to those showing the arrangement of chemical elements in the periodic table.

Marera secondary school

Marera is a day only community school with over 1600 boys and girls. The school is located on the outskirts of Dar es Salaam and it draws students from the surrounding suburbs. Normally around 150 students opt for Chemistry and Physics in Form III. Biology is compulsory for all students.

Typical of community schools, parents contributed a school fee of 20,000 Tanzania shillings (£6) a year for a child. In addition, they contributed towards the cost of stationeries, water, electricity, and security. However, the government abolished these contributions since January 2016 following the implementation of the new Education and Training Policy which recognises ordinary level secondary education as a free basic education in Tanzania.

The overall ratio of teachers to students was slightly above the district teacher-student ratio of 1:33 and far from national teacher-student ratio of 1:26 but within the standard of 1:40 (PMO-RALG, 2014). Generally, science teachers complained about having an extra teaching load compared to their colleagues who taught arts. On average, each of the Physics, Chemistry and Biology teachers taught slightly fewer lessons than the minimum standard teaching load of 24 lessons each week.

Marera had a laboratory for each science subject. These are less equipped compared to those at Getamock though the essential supplies such as water pipes, electricity and other laboratory apparatus were available. Most laboratory tools were kept in the storeroom and brought out only during the practical lessons.

Other classrooms had electricity and there were two water outlets located at the centre of the school assembly area. Although each student had a chair and a table, the classrooms were relatively overcrowded due to the large school population. Typical of most community schools, Marera had up 90 students in some streams. This was more than twice the government policy of 40 students per classroom and far above the district classroom-student ratio of 1:26 and national classroom-student ratio of 1: 43 (PMO-RALG, 2014).

As in most community schools, students at Marera engage in various activities apart from their academic duties. These varied from sweeping, mopping and cleaning surroundings. The school day began with general cleaning under the supervision of teachers on duty. Teaching sessions started at 8.00 am and ended at 3.00 pm with a short 30-minutes break at 10 o'clock.

Typical of other schools, cases of punishment for lack of adherence to school routines and regulation were habitual. Most common included frog jump, kneeling on knees and physical labour depending on teachers' choice. When teaching, teachers also used all sorts of unregistered punishments ranging from exclusion, smacking, pulling hairs, and verbal abuse.

4.3.2 Profiles of the selected teachers

I recruited science teachers based on their teaching experience, professional qualification, and teaching subjects. Although variation in teacher characteristics was not a pre-requisite, I selected science teachers with different experiences and varying demographics to get in-depth insights and enrich findings.

Therefore, I requested a list of science teachers showing their background details from the principals' offices. Next, I identified teachers from the list and approached them individually. I invited eight teachers in total; all the three teachers I approached at Marera participated while only three of the five teachers I approached at Getamock agreed to participate. The two teachers had personal commitments that prevented them from participating. I summarise details about teachers in table 4.1 followed by a brief description.

Table 4.1: Teachers' background information

School	Marerа			Getamock		
Teacher	Alex	Nuru	Deman	John	Alfred	Florian
Gender	Male	Female	Female	Male	Male	Male
Experience (yrs)	5-10	20-25	30-35	1-5	5-10	10-15
Qualification	Diploma(Ed)	BSc. Ed	M. Ed	BSc. Ed	Dip. Electronics	BSc. Ed.
Teaching Subject	Physics	Biology	Chemistry	Biology	Physics	Chemistry

Participants' qualifications varied from non-teaching qualification (e.g. Alfred) to Master's degree in science education (e.g. Deman). Out of 6 teachers, 4 attained their teaching qualifications within the last 15 years. The remaining 2 (Nuru and Deman) joined teaching with diplomas in science education. Although both were eager to study university degree in Education, they could not get admission due to their low performance in the A-level examination. Consequently, they had to join private tuition, re-sit and pass the A-level examination before they could secure university admission. They completed their BSc. with education in the mid 2000's. Deman went further to pursue Master's degree and graduated in the late 2000's.

Alfred's ambition was to pursue engineering after his A-level but he could not secure university admission to an engineering degree. Therefore, he joined a technical college to pursue a diploma in electronics. After graduating, Alfred could not secure employment anywhere apart from the internship with a Telecommunication company. Thus, he joined teaching.

All the teachers were ideally qualified to teach two science subjects but in practice teaching load was distributed such that every teacher taught one main subject. In addition to teaching, Deman, Nuru, Alex and Florian also participated in marking national examination. When teaching, these teachers often shared their experiences of marking national exams with students. These include techniques for answering examination questions, the kind and pattern of answers expected in the national examination. One teacher was a deputy principal and two teachers handled academic affairs, in addition to teaching. One teacher was a facilitator for science teachers' in-service training programmes in the areas of learner-centred pedagogy, competence-based teaching, science practical work and students' assessment for improved examination performance.

Years of teaching experience varied. Deman and Nuru stayed in teaching for over 20 years while John was relatively recent. All teachers recounted memories of difficulties they faced in learning science and passing exams. These include learning science without teachers as Alfred recounted 'since he was transferred, we never had Physics teachers for the rest of the two years'. Thus, they relied on private tuition to succeed in science as John recounted 'I remember those days we had only one science teacher who could be there today but next day he may not. So, I had to join a private tuition'. Others such as Florian held images of learning science in a resource-constrained environment: 'As you know our schools in the villages, we had no readings, for example, it was difficult to know even the topics we were supposed to cover in each class'. Overall, successful entry into science teaching career was an outcome of hard work- tackling contextual difficulties to pass exams and progress to further education.

4.3.3 Data collection

Beliefs are best inferred from what people say, intend, and do rather than directly measured (Glackin, 2016; Hutner and Markman, 2016; Rokeach,1968). This resonates with a view that we tend to learn more about the experiences of others through conversation and dialogue with them (van Manen, 1990). I entered the research site with a desire to elicit deeper stories of science teachers. When narrating their stories, teachers' beliefs, meaning and experiences unfolded. Further, I observed science lessons taught by these teachers not only to get deeper insights into the meanings of science knowledge, teaching and learning that teachers expressed but also the way such meanings manifested in practice. Therefore, I used interviews and lesson observations to collect data because these methods allowed direct access to teachers' meanings, experiences, and practices (Savin-Baden and Major, 2013).

The actual process involved conducting interviews and observations concurrently often beginning with one or two interviews followed by classroom observation and post-observation interviews. Lesson schedules on the school timetable and participants' choices determined interview and observation time. In this way, interviews informed observations of critical incidences during the lessons which I then explored during the post-observation interviews. Therefore, I interpreted practices I observed considering the beliefs about science, teaching and learning that teachers articulated during interviews.

I collected data between July 2015 and February 2016. Initially, I spent two and half months in each school between July and December 2015. During this time, I interviewed teachers and observed lessons they taught, beginning at Marera followed by Getamock. At the same time, I transcribed audio-recorded interviews extending into December when schools closed for the annual holidays. Ongoing transcription allowed the identification of aspects that were worth further exploring during the subsequent interviews with the same participants. Moreover, I conducted follow-up interviews with selected participants in January and February 2016. More details about interviews and observations follow next.

Interviewing science teachers

To develop deeper understandings of teachers' beliefs and produce the most illuminating accounts of their thoughts and experiences, it was important to select a method that permits the researcher to ask, probe and modify questions in ways that suits participants and research questions (Gray, 2004).

I used semi-structured interviews focusing on science teachers' beliefs about science knowledge, teaching and learning and the social and contextual conditions that formed and shaped such beliefs. I formulated an interview protocol (Appendix I) that consisted of open questions, which I clustered into sequential interviews I-VI each focusing on a specific topic (table 4.2). Each question cluster was covered in a 45 minutes interview session with each of the six science teachers.

Table 4.2: The focus of interviews I-VI

Interview	Focus
Interview I	Schooling experience and its impact on the current understanding and practice of teaching
Interview II	Training experience and its impact on the current understanding and practice of teaching
Interview III	Teachers' perceptions of general expectations of students, parents and school administration and its impact on their current teaching.
Interview IV	Beliefs about science knowledge: Knowledge legitimacy, sources, justification, integration, and stability.
Interview V	Beliefs about science teaching: Ideal science lesson, teacher and students' roles, teaching methods and the value of students' prior knowledge and participation.
Interview VI	Beliefs about science learning: Learning intentions, strategies, characteristics of ideal learner and success criteria

I used interview protocol to keep the conversation focused while allowing participants to express their views thus; they determined the order of the questions as the conversation advanced (Lincoln and Guba, 2013). It was during the conversation about these aspects that their beliefs and understandings unfolded. I intertwined most of the interviews with teachers' daily work. Typically, I sat beside the teacher, often in the school laboratories where the offices of most science teachers I interviewed were located. During these moments, teachers often marked test scripts or students' workbooks or prepared lesson notes. I occasionally offered help for example in counting and aggregating students' scores. Thus, some of my interviews often began by picking on what the teacher was doing at that moment. For example, my interview with a teacher who was marking test scripts often started with the question: 'What do students' responses in that script tell you about the success of your teaching? Or what pattern of answers did you expect for this or that question and why?' Next to these kinds of questions, I posed questions from the interview protocol. Occasionally, we planned to have formal meetings with individual teachers during which I asked questions from the interview protocol. Thus, my interviews were both formal and informal depending on the context. With participants' permission, I audio-recorded all the interviews.

Although, I used a combination of formal and informal interviews, I kept control of the process to ensure I elicit quality and authentic responses. I maintained careful attention as participants recounted their experiences, picked and probed on the significant topics to keep the conversation on track. I allowed brief episodes of pauses for the participants to reflect deeply and elaborate further on the points they had made. Silent probe, which may involve remaining quiet when seeking further elaboration about a point was a tactful way to prompt an interviewee to gather memoirs (van Manen, 1990; Gray, 2004). Science teachers espoused beliefs about science knowledge, teaching and learning may not necessarily align to their actual teaching practices, and thus it was imperative to observe the actual lessons.

Science lesson observations

I consider observation as a means of entering the life world of science teachers (van Manen, 1990). I aimed to understand the way science teachers' beliefs are implicated in their actual practices by observing classroom lessons. The way science teachers organized classrooms, carry out teaching, learning and assessment activities can be considered a manifestation of the mental models of good science teaching they hold (Thomas et al., 2001).

Specifically, lesson observation focused on the selected elements of science lessons including physical set-up of the classroom, interaction patterns, nature of learning tasks and activities and the overall classroom culture. I designed an observation protocol (appendix II) in which I divided these broader aspects into more specific elements of the lesson. For example, when observing classroom interaction, I focused on interaction participants and purpose.

I requested to accompany science teachers during the lesson. Often, before the first lesson observation, I explained the purpose of observation and assured teachers of the confidentially. I observed five lessons taught by each of the six science teachers as summarised in 4.3.

Table 4.3: The distribution of science lessons observed

Subject	No. of Theory		No. of Practical	Total
	80 min	40 min		
Biology	4	6	1	11
Chemistry	3	5	1	9
Physics	3	5	2	10
Total	**10**	**16**	**4**	**30**

The school timetable, which reflected curriculum prescription, predetermined the duration of the lesson. In Tanzania, lower secondary school subjects are organized into a single period lesson, which last 40 minutes or a double period lesson, which last 80 minutes and a practical lesson, which last three hours (MoEVT, 2013).

As we entered the classroom, particularly during the first observation, teachers introduced me as a university student learning about science teaching. They did this possibly because I introduced myself as a doctoral student from the university. My identity as a ‘student’ however minimised the power imbalance between teachers and myself. During the observation, I sat at the back of the classroom, observed and took detailed field notes on the events, acts and words relevant to the study. With teachers’ permission, I audio-recorded lesson sessions. I transcribed audio-recorded lessons to supplement my observation notes.

In some practical lessons, I often helped teachers in organizing and distributing reagents and apparatus before the lessons began. This kind of immersion into the daily working schedules of science teachers was an opportunity to understand their practices and beliefs underlying such practices. However, I kept my opinion about teachers’ practices with me and I strived to minimise any interruptions that could result from my presence in the classroom by not interacting with students and teacher when the lesson was in progress.

Post-observation interviews

To understand why the teachers decide to act in certain ways during the lesson, I interviewed each teacher after each lesson. Initially, before the lesson began, I scheduled a post-observation interview session with each teacher. During the lesson observations, I noted incidences and actions that required further exploration to clarify the reasons and assumptions that underlie them. After each lesson, I invited teachers for the post-observation interviews, which often began on our way back to the office. I did this immediately when the teacher’s memory of the lesson was still fresh. I used the exact incidences and actions I noted during observation to prompt conversations. I gave teachers the freedom to discuss the incidences and by doing so, they often talked about other relevant events that I had not initially noticed during observation. Each post-observation interview lasted between 20 and 30 minutes and the conversation was audio recorded. In what follows, I discuss my data analysis approach.

4.3.4 Data analysis

4.3.4.1Thematic analysis

My data constitutes interview transcripts, observation notes, lesson transcripts and my fieldwork diary. I analysed interview transcripts thematically using procedures proposed by Braun and Clarke (2006), van Manen (1990) and Boyatzis (1998). Braun and Clarke (2006) defined thematic analysis as a method of identifying, analysing and reporting patterns in the data. It involves organizing, describing, and interpreting data (Boyatzis, 1998). In doing analysis, I exercised deep reflexivity to grasp the meanings of the experiences expressed during the conversation with teachers. Analysis involved two stages as follows.

Preliminary analysis

I transcribed most of the audio-recorded interviews while the data collection was going on. This allowed the identification of major themes emerging from the initial conversation with teachers. In addition, I identified areas that required further exploration during the subsequent interviews. After interviewing three of the six teachers, I constructed preliminary codes and themes that reflect my interpretation of teachers' experiences. I presented these themes to three participants during the follow up interviews seeking their agreement. This was a useful strategy for ensuring quality and authenticity of my interpretations. Follow-up interviews were an opportunity to reflect collaboratively with participants on the genuineness of preliminary themes I identified. I recorded feedback from these interviews and used it to inform the identification of themes and interpretations during the later analysis which I describe next.

Complete Analysis

I transcribed the rest of the audio-recorded interviews and lesson sessions. Next, I familiarised myself with the data by iteratively reading and reflecting, beginning with interview transcripts followed by lesson transcripts, observation notes and fieldwork diary. When reading interview transcripts, I underlined and circled phrases and words that conveyed the meaning of the experiences narrated for coding. I also wrote notes on the transcripts to indicate potential patterns in the data basing on my interpretation.

Afterward, I generated initial codes from the notes I wrote and phrases and words I underlined. After coding all the data, and generating a list of codes, I formulated initial themes and collated all the relevant coded data onto the formulated themes. Further, I reviewed initial themes to ensure that they essentially relate to the experiences expressed, are internally coherent and clearly distinguishable (van Manen, 1990; Braun and Clarke, 2006). The reviewed themes that surfaced from interviews were used to produce analysis chapters five and six. I present examples of themes emerging from the analysis of interviews that explored teachers’ beliefs about science teaching and learning (table 4.4).

Table 4.4: Sample themes on beliefs about teaching and learning

Phrases participants used			Theme
Deman	**Nuru**	**Alfred**	
• Receiving knowledge • Acquiring concepts • Storing knowledge • Memorising.	• Swallowing concepts • Remember last topic • Answering teacher questions.	• Getting knowledge • Remembering knowledge • Stocking concepts • Answering questions.	Transmissive teaching
➢ Giving science knowledge ➢ Nourish their minds ➢ Cover syllabus ➢ Equip them with knowledge.	➢ Giving knowledge ➢ Flowing ideas ➢ Listening ➢ Getting knowledge ➢ Flowing materials	➢ Giving knowledge ➢ Teaching syllabus ➢ Give solved examples ➢ Give them truth ➢ Giving correct materials	
• Doing frequent exams • Passing exams. • High ranks in exam results.	• Remembering in the exams • Passing exams • Frequent exams • Solve past papers • Show them how to answer exam.	• Passing examination • Doing past exam papers • Comparing test scores.	Facilitating examination performance
➢ Help them go to A-level ➢ Showing them tricks ➢ Enable them pass.	➢ Make them pass Exam performance ➢ Solving past papers ➢ Help them advance.	➢ Passing examination ➢ Examination performance ➢ Giving them techniques.	

4.3.4.2 Analysing teaching: Action-based framework approach

I analysed lesson transcripts, observation notes and fieldwork diary using action-based framework for analysing teaching (Alexander, 2001). When analysing teaching, I focused on the selected elements of the lesson, which reflect teachers' beliefs about science knowledge, teaching, and learning. These include classroom organisation, lessons task, lesson activities, teacher-student interactions, and classroom questioning. Description of how I analysed each element of the lesson follows.

Task analysis

I subscribe to a view of lesson task as what a teacher intends students to achieve (Alexander, 2001). Analysis focused on the 'knowledge dimension' and 'cognitive process dimension' of the task drawing on the revised Bloom's taxonomy of educational objectives (Krathwohl, 2001). Analysing learning tasks by examining task's knowledge and cognitive dimension provide insights into the type of learning teachers seek to promote. I describe the task analysis guide next.

Task analysis guide

Any learning task designed for students to achieve the intended learning outcomes has two dimensions (Krathwohl, 2001). One dimension is the 'type of knowledge and understanding' that the task seeks to promote. Knowledge can be *factual, conceptual, procedural or metacognitive*. Another dimension is the 'cognitive demand' that the task requires students to engage in. The task may involve students in cognitive process of *remembering, understanding, applying, analysing, evaluating* and *creating* (Krathwohl, 2001, my emphasis).

I present both dimensions in a taxonomy table with the 'knowledge dimension' forming a vertical axis and the 'cognitive process' forming a horizontal axis *(*table, 4.5). Tasks increasingly become complex as one moves from 'factual' to 'metacognitive' as well as from 'remembering' to 'creating'. I classified tasks in one or more cells that corresponds to the intersection of knowledge and cognitive process dimension. Classifying learning tasks based on the type of knowledge and cognitive process that the task promotes generated important insights on teachers' beliefs as discussed in chapter 8.

Table 4.5: Taxonomy of learning objectives

Knowledge dimension	**Cognitive process dimension**					
	1.Remember	2.Understand	3.Apply	4.Analyse	5.Evaluate	6.Create
A. Factual						
B. Conceptual						
C. Procedural						
D. Metacognitive						

I analysed 18 of the 30 lessons I observed to categorise tasks considering the type of knowledge and cognitive demand placed upon students when they perform tasks. Analysis focused on the presentation phase of the lesson but not the introduction and culmination phases. This is because tasks in the two phases mainly reviewed the content covered in the previous lessons or the presentation phase of the same lesson.

In addition, I excluded tasks in the four lab sessions from the analysis. Such tasks were replicas of the national exam items and teachers did not design them. When teachers engaged students in ‘exam-based’ tasks their aim was to have students practise exam-type items in preparation for the national exams. Deman explained:

> For subjects like Chemistry and Physics, even in Biology, it is important to use typical questions from the past papers to enable a student to get used to formulas, data collection procedures and calculations. In the exams, even if they can’t do the actual practical, they can write their exams (Post-observation interview).

Therefore, teachers did not intend to use practical tasks to engage students in scientific inquiry the way this is intended in the curriculum. In other words, I considered such tasks less reflective of personal views of teachers. In what follows, I exemplify how I analysed learning tasks in a segment of a Biology lesson by Nuru using the task analysis guide (box 4.1).

Box 4.1: Extract from a Form III Biology, Nuru

(39) Teacher: Correct! Let's now proceed. We have already done spore formation, now we are proceeding with 'budding'. We are proceeding with what?

(40) Students: Chanted 'Budding'

(41) Teacher: Yes! In budding, a new organism is produced from an outgrowth called bud. An outgrowth called what class?

(42) Students: Chanted 'Bud'

(43) Teacher: Good. Examples of organisms that reproduce by budding include Yeast, Hydra and some Annelids. *(She then wrote a definition of budding and description on how budding occurred including organisms that reproduce via budding).* Budding is a form of asexual reproduction in which a new individual organism develops as an outgrowth (Bud) from the parent... Later a new organism detaches itself from the parent and become independent.

(44) Students: Intensively wrote notes as the teacher continued writing on the chalkboard.

(45) Teacher: Re-reads everything she wrote underlining key words and phrases to be remembered. She finalized her explanation with a question made of unfinished sentence: 'Later a new organism detaches itself from the parent and become___?'

(46) Students: Chanted 'independent'

(47) Teacher: I said what organisms reproduce in this way? (*Names were on the chalkboard written as notes).*

(48) Students: Three of them raising hands.

(49) Teacher: Yes, Beda! Tell us.

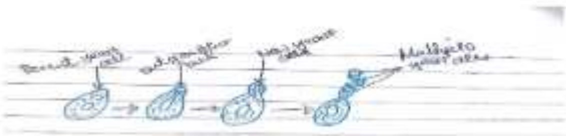
(50) Student: Stood up and answered 'yeast'.

(51) Teacher: Good and what else?

(52) Student: Beda answered again as others didn't raise their hands 'hydra and Annelids'

(53) Teacher: Very good. Now let's draw budding in yeast. (*Draw a diagram to illustrate how budding occurs, then she gave short explanation about a diagram, students listened and copied the diagram in their notebooks*). She concluded by saying 'that is reproduction by......?'

Diagram



(54) Students: Chanted 'Budding'.

(55) Teacher: Let's continue. Another form of asexual reproduction is by fragmentation. Is by what?

(56) Students: Chanted 'by fragmentation'.

(57) Teacher: Joined the chant 'yes fragmentation'. This is another type of asexual reproduction in which an organism divide into two or several parts of equal sizes. Organisms such as amoeba reproduce in this way... (*She continued explaining while writing notes*).

The first task in this lesson is in turn 41 where Nuru introduced the meaning of the terms 'budding' and 'bud'. I classified this as a knowledge of terminology under the 'factual knowledge' category. The cognitive process involved is 'remembering'. To arrive at this classification, I considered the events that took place before and after Nuru introduced the task. Nuru explicitly pushed students to memorise the two concepts by interspersing her verbal explanation with close questions that prompted students to recite (by chanting) the terms ‘bud’ and ‘budding’ (turns 39, 40, and 42). This reflect her intention for students memorise the two terms.

In turn 43, Nuru described the ‘budding process’ and named organisms that reproduce by budding. To classify these tasks, I also considered the events in turns 45-54. First, it appears from the way Nuru described budding process that her intention was to help students receive the description of the process. Nuru portrayed this by reciting a whole description (turn 45) while underlining the key terms to be remembered. There was however, an opportunity for students to make sense of the description she gave thus, I classified this task under ‘conceptual knowledge’ at the cognitive level of ‘understanding’.

Second, recognising the names of organisms that reproduce by budding is a ‘factual knowledge’ and the cognitive process involved is ‘remembering’. I considered closed questions that Nuru asked (turns 47-52) to prompt students to recite the names of the organisms that reproduce by budding to arrive at this decision. The task unexpectedly appeared challenging for students because none of them volunteered to respond though answers were still on the chalkboard. This may be a manifestation of students’ reluctance to contribute ideas.

The task in turn 53 required students to recognise the diagram that illustrates the process of budding. The cognitive process involved in this case is ‘remembering’ and the illustration is a ‘knowledge of models’ which I placed under ‘conceptual knowledge’ category. In turn 57, there are three tasks, first the teacher defined ‘fragmentation’ and gave examples of organisms the reproduce by fragmentation. In both cases, students were cognitively engaged in acquiring and ‘remembering’ the ‘factual knowledge’ (definition and examples). The third task required students to grasp the description of the ‘process of fragmentation’. In this case, the cognitive process involved is ‘understanding’ the ‘conceptual knowledge’ of the process of fragmentation. I presented tasks in turns 41, 43, 53 and 57 in the taxonomy table 4.6.

Table 4.6: Sample categories of tasks (Form IV Biology, Nuru)

Knowledge Dimension	**Cognitive Process Dimension**					
	1.Remember	2.Understand	3.Apply	4.Analyse	5.Evaluate	6.Create
A. Factual	Turn 41 [4]Turn 43_2 Turn 57_1 Turn 57_2					
B. Conceptual	Turn 53	Turn 43_1 Turn 57_3				
C. Procedural						
D. Metacognitive						

Overall, Nuru appeared to focus on helping students to remember and reproduce the knowledge she delivered. This is because she followed her presentation with closed questions demanding students to recite the content she delivered. Nuru often did this while the explanation was still on the chalkboard. In addition, students often resisted questions that demand elaborate responses.

I analysed and classified the tasks in the remaining lessons the same way (see 7.2.2). It is important to acknowledge however, that the clustering of tasks is not straightforward as exemplified above because some tasks could fall in more than one category. For instance, tasks that require students to apply a formula for calculating effective resistance in parallel-connected resistors involves remembering the formula, understanding the relationship between variables in the formula and applying the formula to determine effective resistance. I categorised such tasks into the highest possible category.

[4] Subscript numbers 1, 2, 3…stand for first, second, and third tasks within the same turn.

Analysing classroom questioning

I analysed science lessons to identify the type of questions, purpose of asking, responses sought and the feedback teachers gave following students' responses. I considered classroom questions as statements by teachers aimed to interrogate students' ideas. I selected three lesson transcripts, one for each subject and iteratively read these to identify utterances by teachers that appeared to have interrogative purpose.

Next, I categorised these utterances based on the Question Category System for Science (QCSS) (Blosser, 2000). In QCSS, Blosser grouped science teachers' classroom questions into managerial, rhetorical, closed and open questions. I adopted the descriptions of each category of questions proposed by Blosser (table 4.7). However, I made some modifications on Blosser's initial framework after reiteratively reading lesson transcripts.

First, teachers in this study explicitly sought affirmative responses from students when they ask questions. Affirmative responses indicated that students are agreeing with and are attentively following instructions. Since teachers used 'rhetorical questions' for this broader purpose in addition to emphasising points they made, I decided to use 'affirmative questions' instead of 'rhetorical questions'. An excerpt from a segment of a lesson by John (box 4.2) illustrates how teachers used affirmative questions. For example, in turn 5, John checked if students agreed with the fact that 'a person with blood group AB has both antigen A and antigen B'. He also used the same strategy to seek agreement on what it means to say, 'a person with blood group O has antigen none'.

Box 4.2: Affirmative questions (Form II Biology, John)

(1) *Teacher:* We also said these materials are transported through the blood, which passes through blood vessels to different parts of the body. Blood consist of blood cells, antibodies and antigens, right?
(2) *Students:* Chanted 'Yes'.
(3) *Teacher:* Now each human being has a specific blood type, which is determined by the kind of antigen, and antibodies present in the blood. Do you remember that?
(4) *Students:* Chanted 'Yes'.
[...omitted script...]
(5) *Teacher:* So, a person with blood group AB has antigen A and antigen B. The combination of the two antigens. Right? (*Touched where he wrote letters A and B on the chalkboard*).
(6) *Student:* Chanted 'Yes' (*Agreeing with teacher*).
...omitted script...
(7) *Teacher:* So, a person with blood group O has no antigen? (*Cued question*).
(8) *Students:* Chanted 'yes'
(9) *Teacher:* That is the meaning of none? Is it?
(10) *Students:* Chanted 'yes'.

Second, teachers asked open and closed questions for varied reasons and sought different types of responses. Some teachers asked questions to elicit single word fixed answers while others asked questions to check if students could recall textbook based fixed list of items, events, or procedures. For example, questions requiring students to recite single word answers 'soil', 'electrons', and 'two' are different from questions like 'who can guess the uses of metal hydroxides?', which prompted students to list a predetermined textbook-based uses of metal hydroxides. Considering these variations, I divided closed and open questions into distinct categories as shown in table 4.7.

Table 4.7: Questions category system for science (Blosser, 2000, p. 3)

Question Categories	Descriptions	Examples from this study
Managerial	Questions focused on keeping the classroom going	Only two! Don't you have your notes with you there? (Deman, Form III Chemistry).
Closed-affirmative	Questions requiring simple affirmation by students	You're all right but the correct answer is 25.15, right? (Deman, Form IV Chemistry).
Closed-word	Questions requiring predetermined single word answer	First you take a wire and you connect to what? (Alex, Form IV Physics).
Closed-list	Questions requiring a list of short predetermined answers often one to three words long.	Can you mention others metals which are below in the electrochemical series? (Deman, Form III Chemistry).
Closed-define	Questions requiring short predetermined often textbook-based definition or description of a concept	What is a first aid? (John, Form II Biology)
Closed-procedure	Questions requiring a short-predetermined textbook-based list of events or procedures	What are the three steps do we have to follow when writing a chemical formula? (Florian, Form II Chemistry).
Open-probing	Questions requiring a wide range of justifiable answers with follow-ups beyond the initial answer	NONE! What do you mean when you say the corresponding antigen for blood group O is none? (John, Form II Biology)
Open-divergent	Questions with no definite answers but a range of possible answers	Why do we write a chemical formula? (Florian, Form II Chemistry)

When reading lesson transcripts, I also identified reasons that motivated classroom questioning. I found that teachers mostly asked questions to 'check' students' retention of the previous lesson content. They also 'elicited' either affirmative or single word responses using question tags and declarative statements with omitted words. Occasionally, teachers asked questions to 'probe', seek 'clarification' and 'focus' students' attention to aspects of the lesson. For example, Deman probed 'why a mixture of iron hydroxide and hydrochloric acid shortly changes to reddish brown'. Students' reticence however, constrained this rare but useful strategy of asking questions that promote thinking.

Lastly, I recorded feedback that teachers gave following students' responses. The teachers either did 'not provide feedback' at all or 'praised' and approved answers by giving ‘affirmative responses’. Occasionally, they ‘rejected’ answers, sought ‘collective judgement’ from students or ‘gave a correct answer’ to questions without stating the reason for rejecting students’ answers. I applied the categories of questions, purpose, types of answers and feedback that I identified in the three lessons to the 18 lessons. For each lesson, I tallied the frequencies of each attribute of teacher questions. I present these along with illustrative examples in section 7.2.4.

Classroom interaction analysis

I adopted a view of ‘interaction’ as an exchange involving either initiation, response and feedback/follow-up or initiation and response only (Alexander, 2001; Sinclair and Coulthard, 1992). Each of these aspects of ‘triadic dialogue’ is an ‘utterance’ (Alexander, 2001). I analysed 18 lessons to identify interaction participants and purpose. This involved tallying the number of teacher-class (T-C), teacher-group (T-G), teacher-individual (T-I), individual-class (I-C), individual-group (I-G) and individual-individual (I-I) interactions.

T-C interactions involved a teacher talking to a whole class while T-G interaction involved a teacher talking to students in a group of less than 10 students engaged in an activity. I observed teacher-group interaction in two lessons by Florian (box 4.3). In addition, I counted utterances directed to ‘group task presenter’ as either teacher-group or individual-group. This is because such prompts were directed to the whole group instead of individual presenters (turns 8, 10, and 17, box 4.3).

Box 4.3: Teacher-group interactions (Form II Chemistry, Florian)

1) Teacher: Okay. We start with group 1.

[*...turn 2-7 group one member was presenting...]*

(8) Teacher: Stood up, walked towards the chalkboard and asked, 'okay additional points from the group?'

(9) Group 1 members: No reply.

(10) Teacher: Anything to add to the presentation?

(11) *Group 1 members:* No reply

(12) Teacher: Reaction from other groups? Any reaction from other groups, may be a question, addition, or challenge?

(13) Students: No reply

(14) Teacher: Repeated 'any reaction?'

(15) Student1: A girl raised hand.

(16) Teacher: Yes (*pointing to a girl*).

17) Student1: Stood up and asked 'why do ions bond?' (*a question seemed unclear, not focused but the presenter just responded*).

18) Group 1 presenter: Because they have charges, some have negative charges, others positive charges.

19)Teacher: Anything else?...

T-I interaction is when a teacher talks to individual students outside the context of group or class. This happened when a teacher called individual students to the front to share solutions or demonstrate procedures. Other interactions involved individual students and the class (I-C). Individual students interacted with a whole class when teachers called them to the front either to share their individual solutions or to present group activities (turns 17-19 box 4.3).

I-G interaction took place during the group activity when a member of the same or different group talk to a whole group. For example, when an individual member ask a question to other members in a group without directly addressing a question to specific individual in a group (turns 37-38 in box 4.5). The question was initially directed to a whole group but when the group presenter responded without addressing the concern being raised, the question was directed to her based on the response she gave (turns 39-40). This conversation changed from asking an open question which could be answered by any member in a group to probing on a specific answer given by an individual member in a group. This kind of interaction also changed from individual-group to individual-individual.

Box 4.5: Individual-individual interaction (Form II Chemistry, Florian)

(34) *Teacher:* Turned around, looking for any reaction, then…'no reaction from the group', any reaction from other group members?

(35) *Student:* A girl from a third group raised hand.

(36) *Teacher:* Yes.

(37) *Student:* She stood up and asked, 'what is chemical bonding?'

(38) *Group 2 presenter:* Repeated the definition while underlining words 'is the force of attraction that hold [?] together'. (*The moment she finished the same student who asked the first question asked her another question*).

(39) *Student:* What is it holding? (*The same girl who asked the foregoing question*).

(40) *Group 2 Presenter:* This is a definition of chemical bounding.

(41) *Teacher:* Intervened…

I classified interactions into 'instructional', 'monitoring', 'routine', 'disciplinary' and 'others' considering the purpose (Alexander et al., 1995). While instructional interactions are concerned with the content of the lesson task, monitoring interactions are about the progression of task or correctness of the answers or completed piece of work. Further, routine interactions are those that are not part of the task but took place on regular basis during the lesson. These differ from disciplinary interactions which focus on the conduct of the class or individual students. I tallied interaction participants and purpose for each of the 18 lessons I analysed and presented the results along with illustrative examples in section 7.2.5. In what follows, I describe how I accessed research sites and interacted with the participants.

4.4 Researcher, research sites and participants

4.4.1 Ethical issues

Access

The Ethical Review Committee at the University of Sussex granted permission to conduct the study (Reference: ER/AT401/1; appendix III). At the local level, the Vice Chancellor of the University of Dar es Salaam who is entitled to issue research permits for the academic staff of the University of Dar es Salaam where I work granted the permission to conduct the study (appendix IV). I also consulted local administrative officers at the regional and district levels to gain access to schools (appendix V and VI). I negotiated the permission to invite science teachers to participate in the study through the principals of the respective schools.

Consent

Seeking informed consent involved making participants understand the research and the type of participation sought from them. It involved enabling them to make a voluntary choice to participate and feel free to withdraw at any point during the study. I kept participants acquainted of these important aspects of the inquiry both on an ongoing basis, and most crucially at the beginning of the research as part of informed consent agreement (Lincoln and Guba, 2013). In keeping with this, I described my research to science teachers during my initial visit to schools. I explained its purpose, methods, intended uses, and the kind of participation I was seeking from teachers. I engaged them in brainstorming the potentials risks for their involvement. For example, the ways in which my presence during the lesson could disrupt teaching and learning. Eventually, I gave them information sheets (appendix IX and X) where they could read the details about the research and consent forms (appendix VII and VIII) which they had to sign and return to me just before I began the research. To negotiate informed consent on a regular basis, I asked participants to provide feedback about any aspect of research design and process during the interviews and observations. In this way, I respected participants' freedom and right to withdraw at any point during the study.

Confidentiality and anonymity

Protection of participants' information by obscuring personal information was a priority but an ethical dilemma. This is because the actions I took to keep the ‘particulars’ of the participants confidential inevitably impeded my ability to provide thick descriptions. In qualitative research, thick descriptions are crucial evidence for substantiating the authenticity and quality of the research findings (Bickford and Nisker, 2015). Even with these tensions, I did not overlook preserving participants’ anonymity. Therefore, I compiled, organised and stored audio recordings of the interviews and lessons in an encrypted digital folder. I saved these data on a hard drive, which I kept in a securely locked cupboard that was accessible to me only. Moreover, I checked and removed personal details from the data and I used pseudonyms to identify science teachers (Savin-Baden and Major, 2013).

Case study report by its’ nature almost invariably precludes confidentiality (Lincoln and Guba, 2013). This is because adequate descriptions of the research site may allow a sound conjectures regarding the source of the data. Thus, pseudonyms used to identify science teachers may do little to conceal their identities from colleagues in the same school. A true way of preserving individuals’ identity could be to remove much or all of the information about research site and participants (Bickford and Nisker, 2015). This however, invites readers to generalize findings to any place and time. In this context, I sought a balance by describing the research schools and teachers in a way that minimises chances of identifying the actual participants and sites. For example, to conceal school identity I used ratios, ranges and qualitative descriptors of population relative to national or district statistics.

Ethical tensions of classroom research

Although, the risks associated with conducting research during the scheduled teaching sessions could not be precisely determined in advance, I was aware of the potential disruptions of the normal teaching sessions. An array of foreseen disruptions varied from teachers committing valuable teaching time for my interviews to the disruptions resulting from protocols on the way teachers introduced and treated visitors in the classrooms. For example, students being asked to take extra chair for me to the classroom, students being asked to squeeze together to give extra sitting space for me and emotional discomfort for teachers from being observed. From my experiences of being observed when I was a schoolteacher, I was aware of the possibility for some of these risks. Thus, I took measures to minimise them.

I avoided taking teachers out of the classroom for an interview. I conducted all the interviews either when teachers were in their offices during their free time or when they had seatwork such as marking students' workbooks, test scripts or when preparing lesson notes. I believe times chosen to conduct interviews could not disrupt teachers' schedules in any significant ways. Most importantly, teachers themselves pre-arranged and proposed all the interview schedules.

During the classroom observations, teachers occasionally asked students to take extra chairs from the staffroom or neighbouring class. This was common in the overcrowded classrooms where there were no extra chairs for the visitors. My personal assessment is that this was part of the norms on how visitors and elders are treated in the schools I visited. It was common for the teachers to send a student to get this or that from elsewhere in the school compound. Occasionally, teachers asked students to give a sitting space for me. This sometimes involved asking students to squeeze together in a small bench or chair. In the absence of my visitation, they would not have done that. However, I believe this happened briefly and occasionally. I also believe that the value of the knowledge I was seeking outweighed such minor alterations and disturbances.

Further, throughout the observations I noted very few incidences that I could define as manifestations of teacher discomfort. Those I noted were extra sensitivity to noisy neighbouring classrooms, or noisy groups during laboratory sessions, disappointments, and uneasiness for students' reluctance to answer questions in the classroom. Most of these diminished naturally in the subsequent observations. Although, such anxieties, fears and dilemmas are natural because of the feelings that the observer should see only the 'right things', they may have been reinforced by the power relations between college staff and/or school inspectors on one hand and student teachers or teachers on the other hand. I made efforts to minimise such power relations as discussed next.

4.4.2 Positionality and reflexivity

To acknowledge my place in relation to subject, participants, context, and process (Etherington, 2004), I now describe my familiarity with science teachers and the school contexts in Tanzania reflecting on my background experiences and how these might have influenced the process and outcome of this study.

Generally, during the actual research process a researcher slide on a slippery insider-outsider continuum rather than occupying a fixed location (Merriam et al., 2001). This is because the complexities inherent in the research site blur the boundaries between insider and outsider positions (Merriam et al., 2001). I was an outsider because the site schools were not my work institutions, therefore, I was less familiar with the 'specifics' of the school setting. However, I was a student and later a science teacher in the same school system thus I was familiar with the general aspects such as school routines and curriculum which are common to the school system in Tanzania.

During my schooling and teaching science, I might have constructed certain images of science teachers, teaching and learning. I share grievances common to all science teachers in Tanzania about their professional role, status, and remuneration. Due to these, I might have had some preconceptions of teachers' practices even before the actual encounters. However, I strived to remain open-minded to participants' responses to minimise prejudices on my interpretations. This however, does not fully eliminate the fact that the researcher's values and beliefs inevitably influences the research process and outcomes (Etherington, 2004).

Being an insider however provided chances for enhanced rapport, and ability to gauge honesty, authenticity and accuracy of responses (Merriam et al., 2001). I felt that my insider status allowed me to develop natural conversations and interactions that enhanced the quality of the data I generated and made interpretation a shared responsibility between me as an 'insider-researcher' and my participants as 'insider-practitioners'. Most importantly, the value of understanding the phenomena under investigation outweighed elimination of researcher's biases.

Effects of my presence in the classroom

My presence in the classroom might have influenced classroom dynamics in various ways. The way teachers introduced me to students might have altered the beginning of the lesson. Normally, teachers introduced me to students whenever I accompanied them to class for the first time. This inevitably altered the way typical lesson began.

In anticipation of a visitor, teachers might have altered their teaching preparation, plans and execution. It is a human nature to strive to deliver the best possible whenever one is being observed. To achieve their best teaching practices teachers might have altered their preparation for the lessons. For example, I noted Florian collecting Form II Chemistry textbooks from other teachers and students in preparation for his first lesson that I observed. This was not a routine since Florian did not collect books in preparation for his subsequent lessons I observed.

From my experiences of observing student teachers during the field teaching practice, I think it was likely that my presence in the classroom might have influenced teachers' performance whenever they engaged in 'thinking about being observed while teaching'. When teachers think of being observed, they may become self-critical of their practices or may become distracted from the on-going teaching task.

It is also likely that my presence in the classroom might have influenced learners in some ways. For example, occasionally students patted their disruptive peers on the shoulders with a glance reminding them about the existence of a visitor in the classroom. My presence might have intimidated their cooperative or disruptive behaviours. However, such alterations diminished as more lessons were observed for each of the teachers. I believe repeated observations minimised the impact of my presence in the classroom. Sitting and talking to a teacher for a full day rather than a single lesson observation increasingly made my observations typical.

Further, I blurred my identity as a University teacher to avoid placing myself in a position of authority above the teacher and minimise teachers' sensitivity to being judged. I presented myself as a student who was eager to learn about science teaching. Occasionally, I felt teachers were exercising their powers over me. It was common for teachers to ask for my assistance especially during laboratory sessions: 'Albert can you help distribute these samples! Careful! Put one in every working station'…would you mind distributing these dry cells, I want them to start right away when they arrive' (Albert's notes, 2015). Teachers freely interacted with me because of the rapport I built during my stay in the schools.

Students occasionally asked me questions or pulled me to their discussions during the laboratory sessions when I was moving around to observe their activities. This was an evidence of their confidence in me. I also intentionally dressed casually to blur my image as an authoritative person in the classroom. This made me different from other authoritative figures from the school inspectorate department who inspect teachers' accountability. I cannot claim to have eliminated my strangeness using these strategies. Generally, images of being observed, assessed and held accountable by individuals in position of power are strongly established in teachers' minds. This was part of their teacher education and continues to be part of their professional practice.

4.4.3 Attending to quality

It is generally agreed that interpretive inquirers account for the strategies they attended to in establishing and enhancing the quality of the research findings (Savin-Baden and Major, 2013; Morse, 2015). I employed various strategies to enhance the trustworthiness of both the process and outcomes of this study. These include prolonged engagement with schools and science teachers, persistent observation of the teaching and learning process, member checking of the transcripts and thick descriptions of the context and participants (Morse, 2015).

I stayed in each of the two schools and engaged with science teachers during the normal work hours for over two months. This was an opportunity to build trust and understand the social and cultural context that shape science teaching in schools. By sitting next to participants in their natural working spaces, we could get to know each other and build trust. The more I engaged and interacted with them, the more they disclosed their views and assumptions about science, teaching and learning. The more the researchers are trusted, the better and richer data they can access and, thus the more trustworthy the findings are (Morse, 2015).

I repeatedly interviewed and observed science teachers to get deeper into their thoughts and practices. Repeated interviews allowed the transcription and analysis of initial interviews to identify themes that required further exploration with the participants. In this way, the data become richer and deeper because participants clarified and added on unclear themes. In addition, repeated observations contributed in reducing the 'observer effect'. As I observed more lessons, teachers and students' behaviours and practices become more typical because they became used to my presence.

I transcribed most of the audio-recorded interviews before leaving the research sites. This allowed me to submit the transcripts to participants for review on ongoing basis. I asked each science teacher to check if I fully encompassed their thoughts and if they would like to add any thoughts to what they had already said. I gave participants only the transcripts of the interviews in which they participated. Alfred changed his explanation on the way school authorities interrogated him for declining students' scores in the past examination during the staff meeting. Nuru clarified on the way students reacted when she asked them to read about a topic and present in the following session. All other participants made no amendments.

Towards the end of the data collection, I invited three of the six participants to discuss the initial themes and categories I formulated after analysing the transcribed interviews. I asked participants to provide feedback on whether their thoughts have been incorporated in the themes and categories I formulated. They commented on whether the categories portrayed different ways in which they conceptualise science knowledge, teaching and learning. Participants' responses during this follow-up conversation were audio-recorded and considered during the subsequent analysis.

Finally, I provided detailed descriptions about the context and participants within the predefined ethical benchmarks. This was intended to allow readers of my thesis to determine the transferability of the findings to their own contexts (Lincoln and Guba, 2013). I also presented and discussed findings along with extracts from science teachers' interview transcripts and observation notes to enable readers to access some of the participants' experiences, and practices. I did this in chapters 5, 6 and 7, which I present next.

Chapter 5: Teachers' Beliefs about Science Knowledge, Teaching, and Learning

5.0 Introduction

Teachers, whether they are beginners or experienced, hold tacit ideas about their subject matter, teaching and learning that inevitably influence their teaching practices (Fang, 1996; Pajares, 1992). The key question addressed in this chapter concerns science teachers' thoughts about science knowledge, teaching and learning. I start by describing the way science teachers have constructed scientific knowledge, followed by their beliefs about teaching and learning. I cluster teachers' uniformly held beliefs into themes and sub-themes, as presented next.

5.1 Science teachers' beliefs about science knowledge

This section focuses on science teachers' beliefs about scientific knowledge. What science teachers consider legitimate science knowledge, its nature, structure and progress, influences their preference for and actual adoption of constructivist-based learner-centred pedagogy (Çetin-Dindar et al., 2014; Glackin, 2016; Kang, 2008; Kang and Wallace, 2005; Schommer-Aikins, 2004). Teachers who see science as absolute facts deposited in external authority, including teachers and textbooks, prefer transmissive teaching aimed at equipping students with authoritative knowledge. Conversely, teachers who see science as tentative socially constructed accounts of natural phenomena prefer active and interactive teaching focused at promoting reasoning and negotiating evidence to construct personal understanding. The latter are more likely to facilitate meaningful learning than dictate authoritative knowledge for students to innately absorb. In what follows, I present seven themes showing how science teachers in Tanzania characterise scientific knowledge.

5.1.1 Common-sense epistemology

For teachers, science is a body of facts derived directly through objective observation of natural phenomena. Facts include scientific principles, laws, theories and concepts. Alex remarked, ‘Science is principles! Science is rules! ... I mean science is a body of principles’. Such body of facts mirrors the actual natural phenomena. Alfred exemplified this when he described physics as real facts:

> In physics, you must know what (pause) the reality. That’s why I appreciate physics… because these are real things! I mean these are real things. Even when you just think from the layman’s understanding, you clearly see, isn’t? … the reality of things.

As Alfred explained, teachers believe scientific knowledge is real because they can observe it using their own eyes. Using phrases such as ‘real things’, ‘reality’ and ‘clearly see’, teachers portray scientific knowledge as a description of natural phenomena that is directly observable through senses of perception. Alfred illustrated, ‘When we say incident angle is equal to reflection angle[5]… it’s real, students can see it’. Expounding on this view, Alex asserted:

> The things we teach in science, it’s true they exist. For example, these other theories, like Archimedes’ principle. You may find, for example when you measure up-thrust and the weight of the object when measured in a weighing balance, you will find similar results. It will be the same as the amount of water displaced. This is like what Archimedes stated. The weight is the same as he proposed. Therefore, it is an evidence that you can prove using materials locally available in the laboratory and you will find for sure this is real.

Teachers believe that scientific propositions, which constitute the content of school subjects, are observable entities in an absolute sense. For example, an account of the relationship between ‘incident’ and ‘reflection’ angles is perceived as a fact and free from personal dispositions. For teachers, such accounts are ‘truths’ based on the authority of experts who observed the phenomena and on the veridicality of the observation. Teachers and students, for example, can ‘prove’ Archimedes’ principle by comparing the weight of a floating body with the weight of water it displaces. That is, the fact that the difference in the weight of an object in the air and its weight in

[5] Alfred is referring to the law of reflection of light.

water equals the weight of the water displaced proves up-thrust. When teachers say it is 'real', they mean concrete phenomena in an obvious and absolute sense. Thus, for them, gravity, atoms, genes and similar scientific concepts often inferred from their 'manifestations' are concrete in an obvious sense. Alex illustrated this belief using gravity:

> For example, things like force, we are just told that there is a gravitational force that attracts objects to the ground surface and when you throw an object upward, you will see it coming back but you will not see the force but it's real. It might be abstract and difficult to believe but it's real.

Central to teachers' description of science are notions of scientific 'truths', 'reality' and 'proofs'. For Alex, for example, gravitational force is 'real' in the sense of being tangible and accessible through senses of perception. The fact that the 'objects fall to the ground' when thrown upward 'proves' gravity is real and concrete.

From teachers' perspective, experts write their 'observations' of natural phenomena in books that teachers use to teach. Deman described, 'You're taught in class, that this thing is like this, this and that'. Students also read the books; thus, they acquire knowledge from both teachers and textbooks. To persuade students to accept scientific facts, teachers espouse engaging students in investigative activities for them to confirm the verity of such facts. Deman explained:

> Then, we are not doing things in theory and writings only… that a book says like this. Let me look it myself with my own eyes, you enter the laboratory, you do the experiment, then you come to accept the situation that the theory is real but the experiment is the one that gives us adequate light on how we can put things in the real situation. You do things with your own hands… you go out there and do things while relating with the theories that you got from the class. Then you say it is true depending on the way you observed and practised yourself.

As Deman explicated, students see, taste, and experiment to confirm and accept scientific explanation. The aim seems to give students direct experience for them to confirm and accept scientific truths. Evident in teachers' narratives is the way they interchangeably use ‘facts’, ‘truths’ and ‘reality’ to portray absoluteness of scientific knowledge.

Overall, teachers view science as a body of proven truths derived from empirical observation of natural phenomena. Thus, facts mirror actual phenomena and are verifiable through veridical observations involving senses of perceptions. School science that teachers teach or students read from textbooks comprises scientific facts. Although scientists partly derive scientific knowledge from empirical observation, this empiricist view of science is significantly narrow because a great deal of scientific knowledge is ‘inferential’ rather than concretely observable (Abd-El-Khalick, 2004; Lederman et al., 2002). Scientists make inferences and offer explanations about phenomena that they cannot directly observe via senses of perception (Lederman, 2004). This contrasts with the teachers’ accounts of science, which are replete with examples of both empirical and inferential scientific ‘claims’, but the teachers are inclined solely to empiricists’ views.

In the example of gravitational force that Alex offered, we can see that when objects are thrown they fall to the ground. However, this is only a manifestation of the concept of ‘gravitational force’. The explanation that objects fall to the ground due to gravity is inferential. Similar entities such as up-thrust, genes, atoms, species and electrons, which the teachers in this study frequently use to illustrate their beliefs in the empirical nature of science are products of scientific inferences, imaginations and interpretations rather than precise replica of natural phenomena, the way teachers appear to conceptualise them. These concepts did not emerge from direct observation of natural phenomena; instead, scientists invented and imposed them upon phenomena to interpret and understand the world (Lederman, 2004).

Pedagogically, if teachers are inclined to empiricist views of science, they are less likely to encourage imaginative, inventive, and creative skills among students as emphasised under learner-centred teaching. Teachers are likely to limit investigative activities to confirming known results rather than generating new insights, because they believe that what is known about the phenomena is absolute. Further, if authoritative knowledge is proven, absolute and a complete explanation of natural phenomena, teachers will not encourage students to pursue their own scientific problems, to generate or construct alternative explanations of phenomena. The most logical goal of science instruction for teachers holding empiricist views of science would be to encourage students to acquire expert knowledge. In what follows, I present science teachers' views about the sources of and justifications for science knowledge.

5.1.2 Knowledge authority

Teachers believe that the most credible source of knowledge is a textbook written by experts. This knowledge is perceived to reflect natural phenomena observed by the experts. Subsequently, teachers acquire knowledge from their former teachers and textbooks during schooling. Thus, teachers perceive themselves as knowledge experts and repositories. In short, teachers and textbooks are knowledge authorities. Portraying herself as a source of knowledge, Deman said 'I tell them [students] the truth as it is in the book and they should believe me as their teacher'. This means, as a 'master of subject', a teacher commands a justifiable knowledge authority that students should trust. Evident in the way teachers ascribe knowledge authority to themselves is the idea of teacher as a teller of textbook knowledge. John elaborated:

> I don't think there will be contentions because we have the books as our guidelines. Therefore, it is a matter of referring to our books. Isn't? Because it doesn't mean that what you are teaching is coming from your brain, you

> took it from somewhere. You copied it from somewhere. So, I don't think if your mind is the source, there will be a source! Therefore, you can just show them [students] the source.

In both accounts, teachers depicted textbooks as unquestionable sources of knowledge from which they derive what they teach. 'It is a matter of referring to our books' suggests that both teachers and students must eventually submit to textbook authority. This means that teachers locate knowledge in the external realm different from learners' minds.

Further, it was interesting to explore the proof that teachers provide to justify knowledge claims. For teachers, scientific propositions are 'true' because we can 'veridically' verify them via senses of perception. Thus, they justify knowledge based on sensory perception. For example, the law of gravity is visible in the form of a stone falling to the ground, as described earlier by Alex.

Second, teachers justify knowledge based on their own authority. Like textbooks, teachers command authority for the knowledge they teach. What teachers claim to know is 'truth' because they themselves as authorities believe it to be so. The notion of teacher as a knowledge authority is founded on the essence of 'being a teacher' – a master of the subject. For example, when asked how she could justify her knowledge claims to sceptical students, Deman explained:

> Eeeeh! In fact, I tell the students what is correct. Eeeeh, I tell them to believe what I say. As a teacher, I tell them this is the truth, I can't teach you a lie. If there is a mistake here, just correct it. You must consider an exam answer. The equation needs to be this way eeeh!

They used phrases to justify knowledge such as 'they have to believe me', 'tell them what I know', 'tell them to believe what I say as their teacher' and 'I can't teach them the lies'. The phrase 'as their teacher… I can't teach them lies' indicates the teachers' authority and credibility as a knowledge source.

Teachers therefore interpret students arguing about knowledge as an attempt to challenge the verity of teacher knowledge and as undermining the very essence of teacher as a knowledge authority. Alex illustrated, 'No, a student can't argue with me about physics (pause) teacher that answer is wrong or … that formula is wrong aah no!' For them, students' scepticisms and questions are incorrect and emanate from misconceptions. Alfred remarked, 'It's possible that they read a book but they misunderstood… so I just correct them'. Thus, they advocate identifying and correcting errors in students' queries, as Nuru explained: 'In that situation (when students query) I can just tell them that there is a mistake and because our students believe the teacher knows everything, they can't argue further'. This suggests that teachers might interpret an approach to teaching that requires them to encourage students to scrutinise 'well-established' knowledge sources as an approach that undermines teacher authority.

When students' scepticism emanates from contrasting propositions and assertions read from different books, the teachers believe that they can justify knowledge and truths by evaluating the book itself. Therefore, they 'would ask students to bring a book from where they read a contradictory explanation'. The purpose is to examine and evaluate its validity. Subsequently, they would refer students to textbooks they trusted most. Alex illustrated:

> When what student is saying is wrong and he still hold on that, what I will do is to insist on what I know and believe to be correct and… also, what is written in the textbook. Then, I can give them reference so that they can verify themselves what is written in the book. I can tell them if you read this book or that book you can get your answer or you can check what the truth is.

In this case, the teachers refer students to the textbooks they use in teaching. These are textbooks from which the teachers have extracted ideas and notes to use when teaching. Therefore, when sources contradict each other, knowledge is justified based on the credibility of the source. Overall, teachers justify knowledge based on observation, on teacher authority and on textbooks.

Interestingly, teachers believe that classic books are more credible than current books. They trust the credibility of classic textbooks that they used during their own schooling. Alfred elucidated:

> There are some books, especially new ones that in most cases even myself I don't trust much. Those are the ones which sometimes explain things differently [i.e. inconsistent with what teachers know].

Expounding on this belief, Alfred suggested:

> Then I give them references of about three books. Since we in physics often when we see a concept in Abbot [*Physics* by A. F. Abbott] and then you find a concept in Principles [*Principles of Physics* by M. Nelkon], these books are not mistaken. These books are carefully written… They have tried to explain things carefully.

Indeed, old habits die hard, even for John, who asserted:

> I usually tell them to read good books, like BS [*Biological Science* by D. J. Taylor et al.] or Understanding [*Understanding Biology for Advanced Level* by G. and S. Toole] they don't have to read just any book... there are books when you read you are sure everything is absolutely true.

These views illustrate teachers' well-established confidence in popular classic textbooks that have been in use for decades in Tanzanian secondary education. It is therefore reasonable to believe that teachers might have used some of these textbooks during their own schooling, which might explain their present attraction to such books. Nuru elucidated:

> These current books are different from the ones we read those days. Some topics are new. When you read them, you will find contradicting concepts. Here it says like this, but … the way we know is different. We knew since then this concept was like this, I mean I already set up in mind, that's how this thing is supposed to be, then I find a different thing in the book. In this case, what I do is to consult other books. I consult other books for the contradicting concept, there are those supplementary books, those big books, and I can even consult advanced level books if the topics relate with the one I am looking for.

Likewise, Deman had a similar experience with new books:

> I should say that currently, these people from TIE [Tanzania Institute of Education] brought new books (pause) we call them OXFORD books[6]. Hee! These books are problematic…there're many mistakes. When you take them to class, it's chaos… students keep asking why is this different? Why is it like this? But you said… For example, I taught them 'valence is the number of electrons gained or lost by an element' … but this new book says 'valence is a combining power of an element…'

Evident in these responses are the teachers' resistance to relegate old knowledge. Instead of seeking evidence that justifies ideas in new books, teachers prefer sticking with old books that support their well-established knowledge when resolving contradictions between diverse sources. At a deeper level, this suggests a lack of understanding of a view of science in which multiple explanations of a phenomenon are possible. Instead, the teachers seem inclined to the notion of science as a single definitive explanation for each phenomenon.

Scrutiny of the textbook definition of 'valence' that Deman found contradictory may reveal similarity with what she thought was the correct explanation. That is, because atoms of an element lose or gain electrons to form bonds with other atoms, the number of bonds an atom can form is the same as the number of electrons it loses or gains, which is why its valence can be defined as a 'combining power'. Although science is open to multiple accounts of the same phenomena, the teachers seem to cling to one absolute account corresponding to each phenomenon. Thus, they see an explanation that differs from their well-established knowledge as incorrect. In addition, they may be struggling to understand the explanation they consider to be contradictory.

One could argue that both classic and current textbooks represent different but useful and valid accounts of phenomena relative to the supporting evidence.

[6] These are books published by Oxford University Press Tanzania and distributed to schools by the TIE. The books were written in line with the new secondary school curriculum, which was introduced in 2005 and emphasised learner-centred pedagogy.

Further, the content of the current books that teachers found contradictory is probably more consistent with the new syllabus. However, the teachers' preference for classic texts suggests a limited understanding of how scientific knowledge develops.

Although the production of scientific knowledge itself inherently involves negotiation (Lederman, 2004), the teachers' accounts of science show that they rarely negotiate knowledge with students; thus, they often feel that knowledge justification is unnecessary. This partly emanates from a hierarchical teacher–student relationship, with teachers having authority and control to dictate what counts as legitimate knowledge (Akyeampong, 2017). Teachers, for example, dismiss the possibility of students scrutinising what they teach. As Nuru remarked, 'Eeeh! No, it can't happen. Honestly! A student arguing with me? Haa!'. Expressing a similar view, Alfred humbly commented, 'No! We don't have such students. We don't have such students who can challenge a teacher. Our students believe a teacher knows everything. So, they can't argue with a teacher'. Stressing this belief, John suggested that teachers are superior to students:

> But if that's not enough to justify, what I also believe is that between a teacher and a student (pause) a student! That is a novice brain and a teacher is the big brain, now the adult brain should rule out small brain ha ha ha ha! They say 'a chick cannot teach a hen how to fly'.

The idea of teachers' authority revered for mastery of the subjects they teach is evident in these narratives. The notion of 'big brain' and 'small brain' suggests that students cannot contest, critique or negotiate what a teacher teaches. As Alfred depicted, teachers position students as docile receivers of knowledge. Thus, the possibility of students interrogating teacher knowledge is unlikely. Implicitly, teachers may see learner-centred teaching that demands they regard themselves as facilitators and as spectators of learners who question the 'teacher knowledge' as a type of teaching that undermines the teachers' authority.

In keeping with this, the primary goal of science teaching for these teachers was to deliver 'correct' knowledge for students to receive. When describing her science lesson, Nuru exemplified:

> Even if I am using other methods like group discussions, I have assigned them to discuss, I must have the correct knowledge even if they discuss, and I must give them what is correct. I make sure that I write the right things for them.

Therefore, even when students had prior knowledge of the content or had learned the content using strategies other than lectures, teachers remained preoccupied with lecturing correct knowledge. The idea of correct knowledge, which teachers interpret as 'textbook knowledge', is inherent in the teachers' conceptions of legitimate knowledge. For example, after his Biology lecture on 'methods of food preservation', I asked John how students would have reacted if he had to assign them 'group discussion and presentation' on the same content. He responded:

> They could present… they know them [techniques] very well like salting, smoking, drying or fermentation but these are not like those in the books…they are just used locally…I had to give them the correct ones.

The phrase 'these are not like those in the books' suggests that the teachers believe that legitimate knowledge must be textbook-based. Therefore, despite being aware of strategies that could help students contribute their ideas, the teachers consider such ideas to be illegitimate. This suggests that they assign marginal value to the knowledge and experiences that students contribute when performing activities.

Conversely, the teachers accord high status to textbook knowledge, which they feel obliged to deliver even when students have participated in learning activities that may have been sufficient for them to learn the same content. In short, teachers consider the knowledge that students attain on their own to be of lower value than textbook knowledge.

Students share teachers' beliefs about what constitutes legitimate knowledge. Teachers indicated that students devalue the ideas they generate during activities. Even when teachers teach using strategies that may allow students to contribute knowledge, the students would not consider the ideas they generate to be a valid form of knowledge. Alex asserted, 'If you ask questions they will answer but they [students] cannot consider their answers as the knowledge they are supposed to learn'. Instead, the students still demand that the teachers deliver knowledge, as Alex suggested: 'They will complain this teacher is wasting our time and they will demand to be taught and given notes'.

Students may have been socialised into viewing 'correct knowledge' as that which comes from teachers and textbooks only. Thus, they see their role as submissively accepting such knowledge from authorities. Overemphasis on exams, which test students' memory of textbook knowledge, may contribute to students' perception of their own ideas as inferior knowledge compared with textbook content.

Overall, these results suggest that textbooks and teachers are viewed as the most legitimate knowledge sources. Knowledge in established sources is not negotiable but accepted based on authority. For teachers, a pedagogical approach that allows students to interrogate teacher or textbook knowledge is seen as undermining the essence and authority of such established knowledge sources. Inclined to this epistemological stance, teachers seem less likely to allow space for students to scrutinise and negotiate knowledge sources through seeking evidence and justification as envisioned under learner-centred pedagogy. In what follows, I describe teachers' understanding of how scientific knowledge develops.

5.1.3 Stability of science

The teachers believe that scientific knowledge is stable, correct and definitive. They justify this absolutist view of science using various premises. First, scientific knowledge is definitive because scientists make objective observations of natural phenomena to generate evidence. Scientists subject this evidence to rigorous testing and verification, and once proved true, such evidence remains fixed forever. Florian substantiated this: 'In science when the experiment is done, there is a little room for change… these things like scientific laws and principles that has been investigated and tested for a long time remains fixed forever'. Likewise, Deman believed that 'once the experiment has been done and things have been measured [i.e. tested and verified], we can't throw [replace] away laws… Once established and tested, laws cannot change easily'.

Second, scientific knowledge is definitive because it always corresponds to the real world. Teachers described this as practically testable or 'doing things practically'. Deman remarked, 'Laws are useful in a real situation (pause) we must put laws into real situation. They go practically'. Likewise, Florian explained:

> Science is hands-on. It means we are working; we have hands-on and minds-on. We are doing things practically, so they don't change easily like that... Science has fixed parameters, which do not change at all.

Evident in teachers' accounts is the idea of scientific knowledge as a 'true' representation or description of the actual nature of the natural world. The idea of durability of science knowledge is also associated with uniformity and universality across textbooks. The logic is that, once tested and proved, the scientific account remains uniform and universal across written texts. Alfred explained:

> In Physics, laws like Newton laws of motion have been there for decades, they have been tried and applied all over the world…. for example, laws and principles I teach in Physics are the same (pause), they are stated the same way across Physics books, so it doesn't matter, any book students read these things remain the same.

Teachers used phrases such as 'stated the same across books' and 'any book…things remain the same', indicating their perceptions and expectations that scientific knowledge is uniform across different books. This may partly explain why teachers perceive alternative descriptions of scientific concepts found in the 'Oxford books' to be contradictory.

Teachers' views of the 'universality' and 'fixity' of scientific knowledge, including school science subjects, appears simplistic. This is because such knowledge is based on scientific evidence either empirical or inferential. Rivalry and disputes are inherently part of the processes of collecting and interpreting scientific evidence, which makes multiple (even rival) accounts of the same natural phenomenon likely. Besides, scientists' subjectivity and theoretical positions influence the creation, interpretation, and description of evidence and eventually the knowledge, which forms school science. This means different experts may differ (even conflict) in wording, depth, and content when accounting for the same scientific phenomenon. In short, the science that teachers consider to be a purely objective account of natural phenomena is inherently socially constructed within scientists' frameworks of thinking and their worldviews (Lederman, 2004). Such socially constructed knowledge is subject to review and reconstruction when a different framework of viewing the world is used.

Teachers further justify their beliefs in the definitive nature of science through the consistent use of scientific knowledge. John argued:

> If Biology changes, why would doctors keep learning the same? You see! It's because biology is very important for one to become a doctor. Now, if you tell me it changes, then why are we teaching the same Biology to students who want to become [?] or Physics if you want to be a pilot you must learn Physics isn't?

The fact that professionals and students have continued to learn and apply the same knowledge for centuries confirms, for the teachers, the absoluteness of scientific knowledge. For them, science progresses through the continual accumulation of evidence and through building a knowledge repository. Deman assured me that the Chemistry she has been teaching for over two decades is the same. She exemplified:

> For example, the Haber process I learned during my O-level [?] that was 1988 is the same process I teach in my class. Nitrogen gas combine with hydrogen gas under high temperature and pressures with the help of iron catalyst to produce ammonia, that's it. Maybe there might be additions or elaborations but to make ammonia we use the same formula; the same method you follow, nothing else has ever happened.

For Deman, the fact that she teaches the same Haber process to produce ammonia demonstrates that scientific knowledge is fixed. Teachers may view science as static knowledge if they rely solely on the classic textbooks as their source. Classic textbooks often do not reflect new knowledge developments; thus, they are likely to present a 'fixed picture' of science knowledge.

For example, although the quest for what makes up matter has evolved from Dalton's atomic theory in the 1800s through Rutherford to Bohr's hydrogen model giving rise to modern atomic theory, teachers remain firm with Dalton's notion of the atom. I noted Florian and Deman defining an atom as the 'smallest indivisible and indestructible particle that compose a matter', consistent with Dalton. Yet, atoms are now considered divisible into subatomic particles such as neutrons, protons, and electrons, with some atoms of the same elements having different masses due to the discovery of isotopes.

In the *Structure of Scientific Revolution* (1962), Kuhn argued for the revolutionary as opposed to the cumulative nature of scientific progress characterised by replacement of the old theories by newer ones that are radically different from the old ones. Because many postulates of modern atomic theories contrast with classic Dalton atomic theory, the evolution of atomic theory is a typical example that science does not progress via a series of accumulations of new facts that straightforwardly build on and add to what is already known, as the teachers espouse.

Although current Chemistry textbooks, which the teachers called ‘Oxford books’, present both Dalton’s and modern atomic theories showing how the latter evolved from the former, teachers seem reluctant to accept such new developments. This may be because they have little faith in the accuracy of such books (see section 5.1.2). Therefore, teachers’ overreliance on classic textbooks, which may not reflect knowledge progression, may be contributing to their naïve conceptions of science. Together with authoritarian teaching, which emphasises ‘products’ of science with little focus on how scientific knowledge develops, this appears to conflict with the principles of learner-centred pedagogy, which emphasises presenting knowledge as tentative truths that are subject to critique and change. Teaching about atoms based on such principles could involve introducing Dalton’s atomic model as a rudimentary imagining and an account of atoms followed by later developments emphasising the tentativeness of the explanations, considering that the quest for what constitutes matter is ongoing, and thus existing models (by Dalton, Rutherford, Bohr and Thomson) are all subject to critique and revision.

Apart from their mainstream belief in the absoluteness of scientific knowledge, Nuru and Florian expressed contrasting views when confronted with scenarios that demonstrate that scientific knowledge is subject to revision. They acknowledged that scientists may use the latest evidence to review existing theories, and eventually when the latest evidence is convincing, theory may change. Nuru explained her view:

> We should look at the evidence supporting the two theories and evaluate the one that is more convincing. Normally the early theories or evidence supporting early theories are criticised by the later ones, so it means the earlier ones will have some weakness, so what the later ones do is to create evidence and modify the earlier ones.

Further, for her, scientists could have made errors when collecting initial evidence, or changes in technology could allow collection of more convincing evidence. For Florian, all these may result in knowledge advancement:

> To some extent there is a room for change; human beings practically do science, so there is a possibility for errors… Technology changes, so with modern technology new evidence can be collected using modern tools and this can lead to changes.

These responses suggest that the teachers can concurrently hold absolute and progressive views about knowledge development. They can concurrently believe scientific knowledge is definitive and dynamic. Theoretically, conflicting beliefs can co-exist because beliefs occupy different loci in the belief network (Hutner and Markman, 2016; Rokeach, 1968). Rokeach proposed that core beliefs occupy the centre of the belief network and strongly influence practice more than peripheral beliefs. Although teachers could simultaneously view science as personally constructed truths and as received absolute truths, their core beliefs are more influential to their teaching practices, as discussed in chapter 8.

Although scientific knowledge may be dependable and robust, it is unlikely to be absolute regardless of the enormousness of scientific evidence to support it (Lederman et al., 2002). The evolution of knowledge about atoms, their structures and their behaviours exemplifies the revolutionary nature of scientific progress. Although the teachers in this study appeared to stick to the classic Dalton atomic theory when teaching about atoms, the scientific understanding of atoms has since evolved. This understanding followed critiques and reviews of Dalton's view, giving rise to modern atomic theory as reflected in current mandated Chemistry textbooks.

This suggests that scientific knowledge is tentative rather than absolute as the teachers in this study tend to believe. Scientists can review and replace scientific facts including theories, laws, and procedures when they collect convincing evidence or reinterpret existing ones robustly (Driver et al., 1994). Such sophisticated accounts of science might be beyond the teachers' understanding of science considering that they excessively rely on classic textbooks, which to a lesser extent reflect the revolutionary progression of knowledge.

5.1.4 Monochromatic images of science

Teachers perceive scientific questions and problems as having simple clear-cut right or wrong answers. Scientific questions in this context include questions about natural phenomena asked by teachers and students in their classrooms. They believe that answers to scientific questions are 'real answers' in the sense that they are concrete facts. For teachers, the fact that scientific answers are definite makes it possible to determine precisely right or wrong answers beforehand. John illustrated: 'Science is what, is a real answer. I mean it is one and the only answer, so [?] it is the same for everybody. If you get it right, you get it right, if it's wrong, it's wrong'.

On the surface, this account suggests that the teachers prefer single answers to each scientific question. On a deeper level, it suggests that they believe scientists unambiguously interpret evidence to produce clear-cut answers to the scientific questions they pursue. Conversely, scientists often do not directly discern answers from evidence; instead, they negotiate or conventionally decide upon an interpretation of the evidence and, eventually, upon valid answers to the problems they are investigating (Driver et al., 1994).

Teachers' espoused classroom teaching reflects their beliefs. When describing their classroom questioning practices, teachers advocated asking questions for which they had predetermined answers in their minds that they expected students to reproduce. They believe correct answers are precisely predictable. John elaborated:

> I believe you can predict answers to science questions because we say 95% of answers to questions about science are fixed [absolute], that [?] I mean that when I say what is cytology? And you bring in fanfares which are not about cytology, you know exactly that you're off point.

Likewise, Alex explained: 'I look for a logic behind the question. I mean who has answered the way it is supposed to be answered as per question. Not the way student thought'.

Notably, teachers' preference for fixed and clear-cut answers to scientific questions was clearer in their actual practices. The question 'What can we use to extinguish class B fire?' elicited answers based both on students' everyday experiences and on established scientific views (see box 7.22, chapter 7). Florian rejected responses such as 'covering fire with soil or container', 'using water' and 'fresh tree leaves', which reflect students' everyday experiences of extinguishing fire at home. Instead, Florian's cue elicited the use of 'foam and carbon dioxide', which reflects mainstream science presented in textbooks. This scenario illustrates how context might influence answers to some scientific questions, making such answers less clear-cut. Such answers cannot be judged as 'incorrect or correct' in an absolute sense. In this case, a student is right to name soil, bucket and leaves as means of extinguishing fire based on their local knowledge. Such techniques, though ineffective from scientists' perspectives, remain widely used in the Tanzanian local context.

It could be reasonable for teachers to expect students to demonstrate knowledge of the subject prescribed in textbooks. Further, teachers have expert authority to determine correct answers to the questions in the subjects they teach. However, scientific questions often have no clear-cut answers as the teachers tend to believe. For example, questions about the origin of modern humans, family planning and genetically modified organisms are controversial and prompt value-based answers, which are less clear-cut. Further, rival theories and divergent interpretations of evidence characterise scientific investigations on concepts such as gravity, atomic structure, and biological classification. Thus, scientific accounts of such concepts are ambiguous and not as clear-cut as the teachers tended to portray.

Most importantly, both correct and incorrect responses require due consideration if teachers are to nurture inquiring minds in the classrooms. Since 'uncertainties' are inherently part of the processes by which science 'comes into being' and progresses, when implementing inquiry learning, which models how scientific knowledge is produced, teachers should allow the free flow of ideas instead of demanding students to reproduce correct answers that are consistent with established scientific views.

Nuru and Florian acknowledged slight variations in the way that students answer questions. They felt that their questions may prompt the recall of varied answers because the students read different books. Although the students may express the answers using slightly different words, these teachers still expect the same key words across the range of students' answers. Nuru explained:

> If you ask what's the meaning of laboratory? Everyone [hesitated], the meaning of laboratory remains the same and there are key words (pause), I mean there is [?] what's laboratory? Every student [?] because they read different books, they may use different words, others will say this, others will say that, perhaps they differ one or two words but eventually there is one meaning of laboratory.

As Nuru indicated, the meaning of laboratory is fixed, and students must use specific key words when describing a laboratory. The phrase 'eventually there is one meaning' seems to portray scientific description as a 'true' reflection of nature. Florian used a different topic to illustrate the same view:

> For example, when you ask them to describe circulation of blood in the body, you know Biology [?], Okay! A student may slightly diverge but the content remains the same. If it is how blood circulates, it must start here, it goes there to be oxygenated then it goes there and there! It must be like that. If you explain differently then you are wrong. So, content remains the same. So, they explained like this, went like that, but are they correct? Or they went off point! Eeeh! But at the end thing is the same.

To sum up, the teachers believe that scientific questions have simple clear-cut right or wrong answers. Consequently, when they ask questions, they largely expect single predetermined right answers. Two teachers acknowledged a degree of variation in the way that students articulate answers, yet they expect single correct answers. Teachers' perceptions of scientific questions as having single clear-cut answers may reflect their conception of science as absolute explanations that mirror natural phenomena.

The teachers' view of scientific questions as having clear-cut absolute answers directly contradicts learner-centred pedagogy, which requires teachers to promote multiple accounts of natural phenomena, including students' everyday ideas and experiences of the world around them. If teachers are preoccupied with having students reproduce clear-cut textbook-based responses to questions, it is unlikely that the students will feel safe enough to share their thoughts without fear of being incorrect. Such classroom contexts in which teachers seek single predetermined answers are unlikely to encourage students' thinking and ability to argue a point through sharing multiple ideas including their own everyday experiences. Alternatively, teachers could ask open questions to elicit varied ideas and judge their 'accuracy' based on the evidence and justifications that students provide.

5.1.5 Knowledge (dis)integration

When describing science, teachers talked about the cross-disciplinary connectedness of scientific concepts. This refers to how concepts they teach in one subject relate to concepts they teach in another subject, or how concepts they teach in one lesson relate to concepts in another. I interpreted this as a reflection of their beliefs about the structure of scientific knowledge.

Generally, boundary disputes as to what belongs to which subject are evident in the teachers' accounts. For them, school subjects and concepts within subjects constitute discrete unrelated facts. John elaborated: 'These things are not [?] you can't tell me that there is a connection between my Biology and Physics calculations on pressure or force? I think they are not'. Likewise, Alfred said: 'I don't think there is a Chemistry or Biology topic that is directly relevant to Physics topics. Even Physics topics themselves…you are teaching electricity, how is density relevant there?'

Remarks such as 'How is density relevant there?' suggests that, for teachers, knowledge belongs exclusively to discrete subjects. The subject content stands in isolation from the rest with clearly demarcated boundaries. In keeping with this, teachers of a particular subject perceive themselves as monopolists of their subject knowledge. They espouse encouraging students to stick to concepts they teach, and discourage mixing knowledge from different disciplines. Deman elaborated: 'You see Chemistry is Chemistry, I wouldn't want a student just picking explanation from Biology to respond to Chemistry question… these things are technical if you mix, they don't fit easily'. 'They don't fit' in this context means that the concepts or subjects are unrelated, reflecting teachers' perceptions of knowledge as discrete facts. In other words, they dismiss the possibility of students using knowledge from one subject to answer questions in another subject.

To justify their beliefs in the disciplinary specificity of scientific knowledge, the teachers referred to how textbook chapters are organised. They claimed that even school textbooks are organised by chapter, each one focusing on a specific topic. Nuru remarked, 'Even books treat different chapters separately…because these are not related and if you mix them, it may be difficult for students to understand'. For the teachers, integrating concepts from different subjects or chapters may confuse students. Deman illustrated:

> Even when you teach them the way we do [without connecting concepts] they don't understand, what if you complicate by mixing genetics and growth. Will they?... eeeeh they easily get confused, you know if you talk about ideas in one chapter and then you pick some from another chapter, it's messy for students to understand what you're talking about.

These views suggest that teachers rarely reflect and make conscious attempts to integrate knowledge by linking school subjects to foster holistic understanding when teaching. By referring to curricula documents such as textbooks and syllabi, teachers are indicating that the strong framing of knowledge into discrete subjects is inherently part of the school curriculum in Tanzania.

Indeed, concepts that the teachers mentioned to exemplify their beliefs, including density, electricity, force, pressure, and photosynthesis, are interconnected and not isolated as they tend to believe. Alfred, for example, asked how 'density is relevant when teaching electricity'. In short, the concept of density is relevant when teaching about 'electric current density', which I loosely describe as a volume of current passing across a given area of a wire in a specific time. Likewise, force and pressure relates to osmosis and diffusion in Biology. I used some of these examples to confront teachers, illustrating knowledge integration and exploring whether their views could shift.

For example, I asked John whether turgor and osmotic pressure, which he taught as part of 'transport of materials in plants'[7], relate to 'force and pressure' in Physics. John initially rejected the connection, but after explaining how these topics relate,[8] he commented: 'Aaah! I can now see; they may relate the way you have explained but I have never thought of connecting topics that way'. Similarly, Nuru, who initially rejected the connection between school subjects, also shifted her belief, and commented:

> Let's say in Biology, you have a chapter on cell structure and another chapter on unicellular organisms. Now when teaching about unicellular organisms, you can connect it with cell structure because you will be describing the same structures in an organism with a single cell.

The shift in teachers' views suggests that if teacher educators could interrogate teachers with instances that they cannot explain based on their beliefs, the teachers may change such beliefs. This means that, even if teachers hold belief patterns unsupportive of the envisioned teaching reforms, identifying and challenging such beliefs could help them to develop a sophisticated understanding of knowledge, teaching and learning. In what follows, I present teachers' perceptions of knowing science as reproducing expert knowledge.

5.1.6 Depersonalised knowing

At the core of the teachers' conceptions of science as a fixed 'body of principles' is the notion of knowledge as inert content independent of the 'person' of knower. For

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[7] Transport of materials in plants is taught in Form II, while force and pressure are taught in Form I, as per the current syllabus in Tanzania.
[8] Details excluded to save space.

them, knowing science is acquiring inert content without making personal meaning. In other words, learning science is void of personal interpretation, imagination, and the invention of connections by learners. Alex explained: ‘When I say I am learning science! It means science is a body of principles, which is there, so I am learning a body of principles’. The emphasis is on acquiring uniform knowledge regardless of prior dispositions, which may influence interpretation and connection between ideas that learners make based on contextual and imaginary examples. John illustrated:

> You are just learning but you can’t convert. You can’t say now I have understood Boyle’s law, now let me find a way to state it in my own words. It doesn’t make sense! Ha ha ha! (laughter).

The teachers distinguish learning science from learning other subjects, espousing specific strategies. Alfred explained: ‘To me [?] to me here [?] there is a difference between learning and learning science. If I try to be logical and I stick to science, there is a way of learning science’. For them, learning science involves memorising and reproducing expert knowledge as presented in science textbooks. Alex asserted: ‘I think we learn science concepts the way these are presented in textbooks and we follow the principles of learning science. For example, if we say Archimedes’ principle, you state it clearly as it is in a book’. ‘Stat[ing] it clearly … the way these [content] are presented’ suggests that learning is about reproducing textbook knowledge without negotiating meaning or making personal connections between concepts and wider contexts. Alfred exemplified this impersonal view of learning:

> For science to make sense, it must be stated the way it is in books…when you state [?], when you state [?] you follow the way it is presented… you state ‘when the body is totally or partially immersed in water…’ and you are also learning but not explaining in your own words.

The teachers used phrases such as ‘there is a way of writing its name’, ‘there is a [correct] description in the textbook’ and ‘you must follow the way textbook describes' to emphasise the acquisition and reproduction of textbook content. They advocate 'precision' in the sense of similarity with the original textbook content. Overemphasis on textbook precision may limit students' engagement with knowledge through interpretation and meaning making. The teachers exemplified this view of knowing using concepts from their subjects. John, for example, gave an illuminating illustration using the concept of the 'cell':

> I can say in science we should be precise. Because these are laws, that scientist created and when you look at these, they are real. What students need is to absorb them from a book and not to put [to articulate] the way you think. No, they are there for you to accept. Let us say you are defining a 'cell', there is one definition; a cell is a structural, functional and biological unit of a life of living organism. Different from this it's wrong, you are not defining a cell.

Likewise, using the concept of 'biological population', Nuru emphasised sticking to textbook explanations:

> For example, when you define a population eeh! You must say a population is a group of organisms occupying a niche at a time. You must use the same key words… there must be certain logic; I mean there are certain words which you must write for your explanation to make sense.

The teachers' intended meaning when they say, 'not to put the way you think' was clearer in their practices. To illustrate, in table 5.1, I present sample answers to questions that teachers rejected.

Table 5.1: Rejected answers to teacher questions

	Rejected student ideas	**Correct answer**	**Teacher & lesson**
1	A cell is what we end up with if we divide a living organism into *smallest pieces*.	A cell is a *structural, functional and biological unit* of a life of living organism.	John, Form II Biology
2	When mixture of kerosene and water is poured into a separating funnel, kerosene floats to the top because water is *heavier* than kerosene.	Water is *denser* than kerosene. Light fluid floats.	Florian, Form I Chemistry
3	Solute disappears in solvent but does not change the weight of solvent.	Weight of solvent increases. Matter cannot be created nor destroyed.	Deman, Form II Chemistry

Although students' answers (table 5.1, first column) did not precisely reflect the textbook content, there is a 'grain of truth' in what students said that reflected their understanding. In example 1, a student seemed to replace the idea of ‘structural, functional, and biological unit’ with the notion of the ‘cell as a smallest piece’, which may reflect personal meaning the student constructed for the definition of the cell. In the second case, a student used the everyday word ‘heavier’ to mean ‘denser’, which is conventional Physics vocabulary. Likewise, the student’s answer in the third example is based on everyday experience. That is, when we add a few spoons of sugar or salt in water, the sugar or salt disappears. Although this everyday experience is inconsistent with the law of conservation of matter, which was what Deman sought, it could be supported by students’ everyday experiences. In all three examples, teachers rejected answers based on personal meaning and everyday experience. Instead, they sought answers that are consistent with the canonical science presented in textbooks, often without clarifying why the rejected answers are incorrect.

Overall, the teachers espoused views of knowing science that detaches students’ personal ideas from the process of knowing. They prefer students to articulate scientific ideas using conventional scientific vocabulary, thereby portraying knowing as an objective value-free process. Further, they consider students’ ability to memorise and repeat textbook knowledge as mastery of the subject and as a standard of knowing. Deman explained: ‘I will be sure that they have understood if they can answer my questions… They should answer my questions precisely the way I taught them in class or if they have read textbooks [?]’. Likewise, Florian explained what teachers consider to be valid learning:

> I think in science [?] from my experience, most frequently for sure… when students answer questions they repeat what is there [in books, in teachers notes or other sources], even if it is to add, they don’t add that much unless if it is to give examples from their environment. Maybe that is what I know. But for most of the things we rely on what is written in textbooks.

At a deeper level, teachers' views reflect their conceptions of valid knowledge, which excludes students' everyday ideas and experiences. Instead, answering teachers' questions or contributing ideas in class must involve replicating textbook content, which is what teachers consider to be the most valid knowledge. Under this circumstance, students may not feel free to contribute their own thoughts and understanding, especially when such ideas are not consistent with the 'mainstream science' presented in textbooks.

Since answering questions mainly involves repeating textbook content, it is possible for the teachers to determine correct answers before asking questions during the lesson or in the examination. The impersonal approach to learning provides a sense of security because correct answers are personally independent and universally true. A formula is universally true and anyone can verify it. The correctness or verity of the formula or solution requires neither opinion nor negotiation. This allows the teachers to anticipate uniform responses, and allows students to predict how much they may score in an exam. John illustrated:

> If you ask a definition of 'classification' to all the students, automatically those who will get the definition correct will not differ in the way they define classification. Those who will define it correctly will have their definitions similar. Because the definition must often come from the textbook or notes, therefore all of them must focus on the textbook, there is no difference in what is in textbooks.

Likewise, Nuru explained:

> What I can say is that if you do science test like [?] let me talk about Chemistry, for example, you can know how much you gone score or at least where your score will range. Because (pause), for example may be if it is calculation, you have done it correctly, you have done it the right way and you have correct answers. So, you can predict how much…

To sum up, for the teachers, knowing science is an impersonal acquisition of inert content that pre-exists and is detached from learners. Knowing is memorising knowledge precisely the way it is written in the textbooks. Therefore, learning is uniform for all students regardless of their differences. In this classroom context, where teachers assume knowing is the impersonal acquisition of subject content, it is difficult to see how they can promote constructive learning. One may wonder how would teachers think of or promote learning as creating knowledge if they believe that knowledge pre-exists learners.

5.1.7 Science for geniuses

The teachers believe that science subjects are mostly for students who have inborn intelligence. They highlight intelligence as a key factor that makes some students successful science learners, but not other students. As Deman described: 'What I can say is that for sure you can find most people study science because of their intelligence'. Likewise, Florian said: 'When we talk about science learning, isn't it? I can say student's natural ability is the key, natural ability isn't it... that a person is naturally born talented in science isn't it'.

For the teachers, intelligence is innate and inherited from parents by chance. Parents transfer intelligence genetically to their children; thus, a child is born intelligent or unintelligent. Once born unintelligent, a child cannot succeed in learning science regardless of the amount of effort invested. Alex illustrated:

> Let's take an example, let's say this person, his father studied Physics, his father studied Physics, isn't it? His father encourages him to study Physics hard. Okay! Let's say this person has no natural intelligence, do you think hard work will help him excel in Physics? Never! Or let's say his father has a natural intelligence of becoming a Physicist. Okay! But has not transferred that gene to a child, I mean a child hasn't inherited that gene from his father. And the child is encouraged to study Physics hard, study like this, study hard. Do you think that will make the child excel? Never!

Nuru expounded:

> That's true, it's one's natural ability that plays a role for one to succeed in science. Because even if you work harder I believe, there are things you will be lacking… Therefore, this idea of natural ability I think it counts most for students' success in science.

Teachers drew on their experiences of schooling and teaching to validate their beliefs in innate intelligence. They named individuals who had invested effort in science but had not succeeded. Deman asserted:

> There are people we were studying together and they were using a lot of efforts in studying science but they couldn't make it. For that case, I think this aspect of natural ability is the determinant (pause) that is if naturally you are not fit for science subjects, you can't succeed whatever effort you invest in learning science.

The myth that students who are smart in science automatically perform high in other subjects is very strong in the teachers' accounts. They think that by default, learners who are intelligent and successful in science also perform equally well in arts subjects. John asserted:

> Because they usually say when a person is good in science [?], and this is true, in most cases when you're good in science, these other subjects like history, languages [?] you master them automatically, you also perform well. So, that's true. In most cases, that's how things are.

Considering that the studied schools grouped students into arts or science streams based on their grades in the respective subjects, the teachers ideally expect students in the arts streams to be affluent in arts subjects. Contrary to this norm, the teachers claimed that students in the science streams often outperformed those in the arts streams, even in arts subjects. John elaborated:

> You see! I often hear arts teachers complaining about arts streams because their grades are always lower than science streams even in arts subjects. So, that's certainly true, their performance is poor not only for science subject but also for arts subject they believed to be the best. That makes it even harder to help them!

For the teachers, the phenomenon of students in science streams performing equally well in arts confirms that they were born smart, thereby confirming the teachers' beliefs in fixed intelligence. This also suggests that, for them, intelligence is a generic attribute that determines students' learning success across domains.

The teachers also attributed their own success in science learning to the intelligence they inherited from their parents. Florian, for example, stressed that he and his siblings inherited intelligence from their mother:

> Let me tell you a bit, our mother was very intelligent. She is a person who has inborn intelligence and she was doing a lot of business. The father was the one who did not go to school. Therefore, I believe we inherited our intelligence from our mother.

They perceived parents' accomplishments in life endeavours, educational achievements, and broader understandings as evidence of intelligence. For example, Florian believed the fact that his mother understood many things and ran multiple businesses proved her smartness. He explained:

> We believe that we inherited something from our mother because she is very bright. She understands many things although she has never been to school… Yeah! She is this person running multiple things. Therefore, some of us we took intelligence directly from our mother, that's why we have been successful. Like my brother when he went mad! Many teachers cried, even the headmaster cried. They felt they had lost a very brilliant student.

Consequently, the teachers often conjecture students' success or failure from their parents' status. For them, children whose parents are engaged in renowned occupations are potentially intelligent. Parents' success indicates children's smartness and a predictor of learning success.

Teachers believe one's inborn intelligence determines learning success and exam results; therefore, such outcomes are beyond their control. In keeping with this belief, the teachers feel 'helpless' when asked about improving the learning achievement of students they consider to be unintelligent. Deman explained:

> It is very difficult… Students who are incapable even if you put more effort on them, they may improve very little. Maybe if they were scoring 20, they can reach 25, but you can't push them very much because their ability doesn't reach there.

They consider dedicating efforts to low-achieving students to be unproductive because such students are simply unable to improve. These beliefs appear to have shaped teachers' decisions and behaviours towards students with low performance in science. The teachers admitted that when they become sceptical of students' ability to succeed in science, they often advise them to withdraw from the science streams. Deman explained the practice:

> It is here when we tell the students that based on your ability… this subject is for those who have a little bit higher ability. Otherwise, you should not insist on taking it and end up getting a zero in your Form IV exams.

The teachers consider withdrawing such students from the science streams to avoid undesirable failure in science exams. This means they attribute low achievement to lack of inborn intelligence, which is beyond their control. At school level, the screening of students to identify those who are 'fit' for science subject territories and streaming to eliminate the 'unfit' implies that the 'intelligence myth' is deeply embedded in school decision processes. Florian, who was a deputy principal at Getamock, supported this practice in his school:

> We decided that these students, it would be good to drop them from science. We should take them to other subjects … at least they will have few subjects.

The teachers advocate dropping students from science streams even if the students are enthusiastic about pursuing science as Florian explained:

> Even though they complained and they wanted to remain, we thought no! They should use most of their time to read the same kind of things rather than struggling with science that for sure they had no ability to learn. They can't! And for good intentions, we thought they should do that. Myself I am a Chemistry teacher but when I realise that a student can never succeed in science because of limited ability, I can't lie, why would I continue encouraging while I know they will score zero?

Overall, screening and ability grouping students based on exam scores might have reinforced the view of intelligence as a fixed attribute that determines learning success. Since this is a well-established practice in the context of secondary education in Tanzania, the teachers might have experienced the same during their schooling.

Whereas all the six teachers perceive innate talent to be a key success factor for science students, Alfred also held a contrasting belief. He indicated hard work and environment as additional factors. Alfred asserted:

> If you can (pause) if you can work for it, you can succeed although it is not enough to make someone a scientist, but if you can work on it, you can succeed… They can pass even if they don't have that much intelligence, you will find some of them just have the average ability but they work very hard. They use what they have and they can pass.

For Alfred, some students might have average ability, yet they learn successfully if they take their learning seriously and work hard. He explained: 'after working very hard, they re-took their exams and they are now successful. You see something like that!' This means that learning effort is key.

Alfred further argued that, while the perceived difficulty of science subjects motivates some students to devote efforts and succeed, others become scared and give up science. He said: 'There is a mindset that science is difficult but probably the truth is that it is not that difficult (pause), is just a mindset that frightens others but for others, it encourages them to work hard'. When faced with a difficult (but within their capacity) task, students who strongly believed that the ability to learn can improve will persevere and attempt diverse strategies (Schommer-Aikins, 2004). Collectively, the teachers' responses suggest that they perceive intelligence to be key to success in science learning. Whether intelligence, efforts or both count in predicting learning success is debatable.

5.1.8 Section summary

Overall, the teachers perceive science knowledge as an absolute body of facts derived from objective observation of natural phenomena. Facts reflect faithful copies of concrete natural phenomena. In the classroom context, the teachers see themselves and textbooks as the most credible sources of knowledge. They justify their knowledge claims by stressing what they perceive as scientific truths and refer students to textbooks for further evidence. The teachers view knowing science as absorbing and accumulating discrete pieces of textbook content. They believe that naturally born intelligent ‘students who are fit for science’ can achieve this efficiently.

When challenged with alternative propositions, two teachers shifted their beliefs towards accepting the tentative and complex nature of science knowledge. This was different from their initial views of science as discrete absolute facts. This resonates with a widely held view that individual teachers may hold a set of conflicting views about the same topic (Koballa et al., 2005). Predominantly, teachers’ beliefs about scientific knowledge conform to what Perry (1970) called ‘dualist beliefs’ or what Schommer (1990) described as ‘naïve beliefs’ about knowledge. In what follows, I describe teachers’ beliefs about teaching and learning which appears to reflect their conceptions of scientific knowledge.

5.2 Teachers’ beliefs about teaching and learning science

While the basic principle underlying the curriculum in Tanzania is that the best teaching and learning occurs when teachers help students to discover and construct knowledge on their own, this vision seems to conflict with the established beliefs that a teacher is an authority entitled to tell students the facts they are supposed to know (Bruner, 1996). I organise teachers’ beliefs about teaching and learning under five broad themes, which emerged from analysing instances during which the teachers described ideal science lessons. I discuss each theme in turn in the next subsections.

5.2.1 Transmissive teaching

The teachers unanimously view teaching as getting across mandated textbook knowledge for students to acquire. The essence of ‘being a teacher’ embodies the possession of authorised version of knowledge and expertise in the subject one teaches. Therefore, teaching is about effectively conveying pre-packaged knowledge for students to receive in its complete form. Alfred explained: 'I teach them, give them knowledge, derive formula and give them solved examples'. Similarly, Nuru suggested: 'When preparing for a class, I think of the best way to get across what I have [content knowledge]. I want them to get it…I ask them 'have you got it?' Deman further expounded: 'I make sure that they get the knowledge that they are supposed to get… I must give them knowledge and we stick to the topic as per syllabus'.

When teachers say, 'knowledge which they are supposed to get', they mean the science content prescribed in the mandated textbooks. Teachers also used other phrases such as 'what they are supposed to know', 'what they should know' and 'the way they are supposed to know' to portray mandated textbook content. Further, 'getting' and 'knowing' mean acquiring and building a knowledge repository.

Therefore, the objective of teaching, for them, is to transfer unaltered knowledge from textbooks to students' minds in the form of explanation. To achieve this, the teachers emphasised systematic transfer of knowledge with minimal interruption, as Alfred described: 'The teacher has to be systematic (pause) when you enter the class you just flow…No fumbling at all'. They articulated this view of teaching using descriptors such as 'flowing', 'flowing materials', 'explaining and explaining', 'spoon-feeding', 'talking and talking' and 'writing notes for students'. Nuru exemplified:

> When I enter the class eeh! It is a matter of flowing. Even students usually cheered 'madam give us the material. Give us the material…' so, my task is to flow and feed them as they expect.

The teachers illustrated transmissive teaching in concrete terms when they described their best lessons as Florian explained:

> When I enter the class, I begin talking about important facts and concepts we learned in the previous lesson and students love it! For example, when I enter the class, I tell students may be last time we meet I talked about Faraday's first law of electrolysis. Then I state the law. Faraday's law states that 'the mass of a substance produced by electrolysis is proportional to the quantity of electricity used'. Then I derive the formula and give them solved example to remind them. Then, I tell them today we are going to proceed with the Faraday's second law of electrolysis (pause)…which states that 'the amount of electricity in coulombs required to produce one mole of a substance is the whole number multiplied by 96,500'. Then, I derive the formula and give them examples of how to go about solving calculations involving Faraday's second law of electrolysis… then I wipe the chalkboard and write notes for them to copy.

Similarly, Alex explained:

> You just teach… definition of current electricity, you explain how it's measured… you draw series [?], this is a series connection, this is a parallel connection, if you want to find out the amount of resistance or the amount of voltage that passes through this wire you use the formula [?], you give them a formula ha ha ha! And that voltage at this point is the same as this point….

The foregoing excerpts from lessons by Nuru, Florian and Alex illustrate how the teachers can enact transmissive teaching. They described teaching as explaining facts, deriving formulas, showing procedures, and giving solved examples. The teachers are preoccupied with delivering subject content, which forms the core of their professional authority and identity. The essence of being a teacher is exercising control over choice, organisation, and delivery of legitimate knowledge. Evident also is the passive role of students. They listen, answer the teacher's questions, and write notes. As Nuru suggested, students cheer teachers on, who then demonstrate mastery of content to validate their professional identity.

In addition to knowledge delivery, teachers also stressed writing lesson notes on the chalkboard as an important aspect that symbolises teaching. They feel that providing lesson notes is an obligation and important for students' approval and satisfaction. John explained:

> Yeah! Because among the things the teacher is required to do is to prepare lesson notes for students. And as I said, if I only ask them questions, they [students] will say the teacher didn't teach us. They will complain I didn't teach them and will demand lesson notes.

Perhaps students perceive the notes provided by teachers to be more useful and a simpler way to grasp the content they need to pass examinations. They may also find exploring learning material on their own to be more demanding than memorising lesson notes. However, overall, teachers and students seem to have constructed good science teaching as explaining and writing notes. Consequently, students view teachers who demonstrate masterful delivery of subject content as the best teachers. Deman elaborated: 'In most cases, a good teacher is the one who knows a lot… a teacher who can flow, they want me to flow ideas'. Alex explained further:

> Because you know, students will lose trust in you if you are uncertain with what you are teaching. They will say this teacher is shallow! So, when you teach them you try to explain as much as possible… and write lesson notes for them.

As Alex indicated, it is unthinkable to imagine a teacher failing to demonstrate mastery of subject content. Students would consider such teachers to be shallow, incompetent, and untrustworthy. At a deeper level, this indicates that teachers' authority and legitimacy rest on their demonstrated mastery and delivery of subject content. In this context, a pedagogy that requires teachers to 'act' as facilitators, learners or colleagues may undermine teachers' legitimacy and authority. In the teachers' views, facilitating students to engage with the subject matter and arrive at their own conclusions, instead of providing them with facts and answers, would undermine the teacher's authority in the classroom. Consequently, to meet students' expectations of good teachers, and show mastery of subject content, the teachers admitted grappling with textbook content to ensure smooth delivery. This was also an attempt to legitimatise their professional authority. Deman disclosed:

> Because they expect me to give them knowledge, before even going to the classroom, I checked the topic I am supposed to teach. I made sure I have a knowledge and students get it.

In short, teaching without good knowledge delivery is ‘incomplete’. Therefore, even when the teachers are aware of interactive teaching strategies such as group discussion, they remain less enthused to implement them. Even those trying to employ such approaches often remain focused on content delivery and reteach students what they have already learned on their own. Alfred explained:

> It is very important for me to explain these concepts and give them notes; even if I assign them into groups … otherwise they often complained this teacher is not teaching, this teacher is not doing this.

The underlying belief is that teaching science must involve content delivery. In this case, knowledge is something that pre-exists students’ engagement with it; thus, teachers must transfer it to students. There could be multiple reasons to explain this belief. For example, teachers may believe that students have limited access to textbooks and thus they see lecturing and writing notes as an effective way to disseminate knowledge to a large number of students. Further, it could be that teachers and students devalue learning achieved through active approaches. At a deeper level, teachers might feel that approaches to teaching that require them to relegate control over what, when and how students learn undermine the essence of their presence in the classroom.

Consistent with their conception of teaching as conveying knowledge, the teachers described learning science as receiving and accumulating scientific facts. This partly follows from their views of knowledge as impersonal truths that students need only to acquire. Such learning neglects the personal processing of knowledge such as negotiating meanings and interpretations as well as making intuitive connections between ideas and meanings. Alfred remarked: ‘All those Chemistry reactions he swallowed them… He had absorbed everything'. Likewise, Nuru asserted: 'We say it is more of swallowing. We strive to teach them and motivate them to revise it repeatedly, so that they can keep it until the final examination'.

Further, teachers espouse passive learning activities such as listening, memorising, rehearsing, watching teacher demonstrations and copying lesson notes. Nuru illustrated:

> So, when they listen I give them knowledge, they get knowledge (silence), know the concepts I teach them in class and use it when they are doing their final examination.

These strategies hardly promote any learning beyond recall of knowledge. Indeed, the teachers advocated encouraging students to memorise knowledge they receive. For example, Deman and Florian described two interesting techniques that reinforced students to rehearse and memorise the first 20 elements of the periodic table. Deman provides students with a mnemonic for each element:

> Usually, I give students mnemonics or acronyms to help them do what [?] To help them remember these concepts… like the first 20 elements.

Florian, conversely, asked students to sing the first 20 elements at the beginning of every Chemistry lesson in place of customary greetings. The aim of this is to help students exactly replicate the knowledge that the teacher delivers. To achieve this goal, teachers and students emphasises obedience, attentiveness, and adherence to instructions. Teaching through memory-enhancing techniques such as mnemonics is characteristic of teachers holding superficial conceptions of learning (Brown et al., 2008).

Teachers advocated asking questions that require students to recall content knowledge they have acquired, to demonstrate learning. They consider students' recall of factual knowledge taught in class as a standard and as evidence of successful teaching and learning. Deman substantiated this when she explained why one of her lessons was successful:

> They answered most of the questions correctly in the exercise I provided so I think they have learned…But they got most of them correct so I believe they have stacked things in their minds.

This substantiates teachers' perception of learning as accruing science knowledge, a view which rests on the assumption that students are empty 'receptacles' to be filled with knowledge. This concurs with what Paakkari et al. (2011) called 'learning as a reproduction of acquired knowledge'. Under this conception, Finnish student teachers viewed learning as the acquisition of unproblematic facts through rote learning strategies such as memorisation and repetition.

5.2.2 Facilitating examination performance

Examination surfaced as a powerful factor that shapes the teachers' understanding of teaching and learning. This is because they perceive science teaching as equipping students with the knowledge, skills, and techniques they need to pass examination. Although the essence of teaching is still to convey knowledge for students to acquire, the teachers encouraged students to revise the knowledge, to optimise recall during examinations. Deman explained:

> I must give them the knowledge that will later enable them pass their examinations and can advance to the next level of education (pause) which will finally enable them to achieve their target like being a medical doctor, nursing.

Teachers feel strongly obliged to teach students and ensure they pass examinations. Alex further explained: 'I have to enrich their minds with good knowledge [?] I explain concepts for them, make notes from different books, and give them to read so that they perform well in the examinations'. Similarly, Nuru stressed this view when she described the purpose of teaching:

> The aim is to make them pass. You teach students and they expect to pass but if it happens they fail your subject, what do you think will happen? Will

> they applause you? 'Teacher, you taught us well but we have failed!' (sarcastic laughter).

These assertions evidently portray teachers' conceptions of teaching as preparing students for examinations. Deman's phrase 'give them the knowledge that will later enable them pass their examination' illustrates that not all knowledge counts, only the knowledge that students can use in examinations. Teachers still view knowledge as textbook facts and learning as accumulating knowledge; however, they focused strongly on encouraging students to acquire the knowledge they need to pass examinations. John asserted:

> The aim is to have them pass their exam. To succeed first is to pass the exam. Therefore, we just prepare the students to ensure they fulfil their aspirations. That is all we can do.

This view suggests that learning is primarily for passing examinations. To achieve this fundamental aim of learning, the teachers strongly feel responsible for inducting students in techniques that can help them answer examination questions. They espouse inducting students in techniques for locating, formulating and presenting the answers that are expected in the examination. In doing this, they draw on their experiences of marking national examinations to help students pass. From their experience of marking national examinations, these teachers knew the type and standard of the answers expected. Thus, they coached their students in techniques for framing and answering exam questions. Florian explained:

> There is no secret in chemistry teaching. But various techniques I used, solving questions for students in class. Sometimes they do these themselves because they know I am too strict that they must solve. For example, if I say, today we are going to solve 2012 national exam paper everyone must read it. Everyone should find answers and when we come to class, we discuss.

Likewise, to realise this vision of success, Deman explained her strategy:

> The most important thing is frequent, up to date standard examination…and this has made us the first school among the 48 government schools in the district… We use many techniques, there is remedial teaching where we

> show them how to answer questions…we give them techniques for answering questions in the examination, solving many past paper questions and many other techniques for enabling them to pass exams. Giving them frequent tests more than it is prescribed in the syllabus to prepare them well.

I personally witnessed this practice during the fieldwork in both schools. At Marera, where Deman teaches, students took practice exams and tests every Friday of the week. The items for practice exams are drawn from the past national examination papers.

From teachers' accounts, it is evident that students are also accustomed to examination-driven teaching and learning. For example, to establish that they had mastered the content of a given topic, students checked their knowledge by attempting questions in past examination papers. John explained: 'They go and check questions in the past papers. They try to solve them and see if they can solve them, then they are happy, they know they can pass'. Therefore, passing exam is a desire for both teachers and students.

Beyond the teachers, the education structures also support examination-driven teaching and learning. During the interview, Deman revealed that, besides orienting students to 'exam-taking skills', she also trains teachers in techniques for identifying action verbs such as discuss and enumerate, which form the stem of exam items and the answers. The district education authorities support her initiatives to train and mentor teachers in how to achieve these standards.

> They [district education officers] are concerned about improving examination results in [name of district], that's why they asked me to prepare all the action verbs describe, discuss, substantiate, what is the difference and what a student is required to do when you find such action verbs.

These accounts confirm that teaching geared at preparing students for exams and improving standards is the primary goal pursued by both teachers and district education authorities. Overall, the teachers modify content, methods and teaching techniques to contribute towards students' performance in the exams. Teachers consider learning to have taken place when students can recall correct answers to exam questions. Along with the mainstream beliefs that I have described so far, three teachers advocated teaching through activities, which I describe next.

5.2.3 Facilitating activities

Three teachers described teaching science as engaging students in various forms of activities, which varied from teacher-led demonstrations to student-led laboratory work. The most frequently named activities include answering teachers' questions, writing notes, reading, assignments, homework, teacher demonstrations and laboratory work. Deman illustrated: 'As one of the science subjects, a properly and successfully taught chemistry lesson should be activities oriented. Involving students more both theoretically and practically'. Similarly, John illustrated how activities may be organised during a typical lesson:

> Therefore, I usually give questions for students to search materials themselves… They search even if it is in books. If it is to discuss with colleagues, they search for those answers, I give them time for them to provide or present the answers they have. Afterwards, I sum up, do corrections and give comments.

These responses suggest that these teachers support teaching that creates a space for students to experience knowledge through activities. However, the teachers also gave responses that suggest that they remain largely focused on enabling students to acquire the subject content that they need to pass examinations. This is because, in their descriptions of activities, teachers often prioritised knowledge delivery through lectures to precede the student activities. Exemplifying this order of lectures followed by activities, John said:

> They learn theory in the class first, I explain and they listen. For example, if I am teaching the structure of a flower, I name and describe its parts, then I draw diagram to show the parts after which I take them to the labs to do what? Experiment… They can see it for themselves. I can assign them to cut a

> flower, observe its parts; they can use a hand lens or microscope if they must observe tiny parts like pollens. They also draw what they have seen.

Deman also illustrated this order of teaching, by using examples. First, she said:

> After acquiring theory in the classroom, a student is required to go to the laboratory again to be able to acquire more knowledge. They touch, manipulate, hold and observe the outcomes. That is when the beauty of Chemistry is manifested.

Then, she illustrated this by using the concept of the ‘preparation of oxygen’:

> When they are learning ‘preparation of oxygen’ for example, I can start by giving them what they are supposed to know. The reagents required the procedures [?], I explain everything, draw a diagram and illustrate using equations […] You pour hydrogen peroxide into a conical flask containing manganese IV oxide which is a catalyst, then you fill beehive shelf with water and gas jar on top of it, upside dawn…. They listen to me and look at the demonstrations but it is not just listening to the theory. They need to see, do it themselves to believe…. But it is difficult here anyway.

A closer look at the teachers’ accounts about how they visualise lessons that engage students in activities may reveal three important reasons for engaging students in activities. Notably, teachers largely assign activities to supplement lectures, during which they deliver prescribed textbook content. As Alex and Deman indicated, they assign activities only after delivering the content that students need to acquire. This suggests that engagement in learning plays a subservient role in teaching and learning. Thus, an approach to teaching that engages students solely in inquiry activities is regarded to be ‘incomplete teaching’. John expounded on this when he said: ‘I must teach them first; next I give them group work to see how they will do’. The phrase ‘I must teach them first’ suggests that the teachers prioritise knowledge delivery through lecturing over student activities. In short, for the teachers, teaching is primarily a form of ‘direct instruction’ about the subject content.

The teachers may prioritise content delivery over inquiry activities if they believe this could optimise examination results. Perhaps ideas contributed, generated or learned during activities do not contribute directly to passing examinations. It may be that teachers and students perceive these as valueless and an illegitimate science knowledge compared with textbook knowledge. Teachers believe that the acquisition of a good amount of factual knowledge is mandatory, in contrast to learning inquiry skills through activities.

Teachers consider learning activities to be a means of persuading students to accept scientific truth. They believe that these activities could give students direct experience of natural phenomena through observing, touching and manipulating. The phrases ‘they can see it for themselves’ and ‘they need to see… do it themselves to believe’ are indicative of the role of activities in persuading students to believe theory. In other words, for the teachers, the primary purpose of engaging students in activities is to prove the verity of theoretical knowledge.

Indeed, most of the activities I observed during lessons focused on corroborating correct answers, which the teachers often knew beforehand when assigning activities. Consequently, activities constituted procedural tasks focused on helping students arrive at correct answers, often with minimal intellectual engagement and abstract reasoning. This appears to relate to teachers’ conceptions of science as facts derived from unproblematic observations of natural phenomena.

Lastly, John and Alex described student activities as opportunities for teacher–student interactions. While for Alex question-and answer technique is a way of assessing learning: ‘I prefer questions and answers because it allows me to interact with them to find out if they are learning’, for John it’s a way to engage students in competition:

> Before I start a new lesson, I ask questions about any topics that we have covered. I normally ask them to remain standing. Let us say I have ten questions with ten points. I ask a question. When any boy responds correctly, boys gain a point and when any girl responds correctly, girls gain a point. The

> group that gains most points will seat when all questions are over. Therefore, it was the competition for seats.

Visualising student activities as opportunities for teacher–student interaction suggests preference for a pedagogy that encourages student participation. This may indicate the influence of widely promoted learner-centred teaching in which student participation is emphasised. Some of the activities could be a means to motivate students to memorise the content taught in class. In describing a question-and-answer strategy, teachers advocated asking questions about the content of the previous lesson. This may be a way to highlight what the teachers think students need to memorise to pass exams. Although engaging students in learning activities could promote deeper understanding, teachers' descriptions of teaching and learning through activities revealed several limitations.

Teachers espoused assigning highly structured and teacher-controlled activities. This was evident in the examples teachers gave, in which they espoused initiating the activities themselves instead of negotiating these with students. Typical examples are demonstrations and question-and-answer sessions, which are mainly teacher-led. Their accounts suggest that students' participation is limited to watching and responding to teachers' questions. Moreover, teachers admitted planning these activities in advance, often without negotiating and considering prior knowledge and learning needs.

Although practical work and group discussions could potentially promote active participation and deeper understanding, teachers stressed prescribing recipe-like procedures for students to follow and to arrive at the expected answers. Alex exemplified that he would 'assign students to cut flowers, observe its parts…and draw diagram'. Prescribing and executing practical work in this way could potentially result in loss of learning value. This is because, when activities are structured, students' cognitive engagement may be minimal, and so the possibility for deeper learning may also be minimal. Structuring activities may restrict learning to manually following the set procedures, thereby lowering mental engagement. In short, structuring tasks predetermined the level of students' participation, as John clarified:

> Their participation is on what you are teaching. Not on how you teach. I mean their participation is restricted to what you want them to do. The teacher–student participation differs in percentage. One must participate more and another one should participate less.

Overall, in addition to their beliefs that teaching is about delivering knowledge, Alex, John and Deman view teaching as facilitating student activities and learning as participation in activities. They advocated highly structured activities aimed at supplementing lectures. Such activities were not considered proper teaching unless content delivery with students listening and watching is involved. This may restrict the extent to which students can achieve deeper learning. John and Alex espoused a more sophisticated view of teaching as facilitating students' understanding, which I discuss next.

5.2.4 Facilitating understanding

Although John and Alex still stressed ensuring that students acquire the prescribed textbook knowledge that all the other teachers consider essential for passing examinations, these two teachers also recognise the importance of students understanding the textbook knowledge. They advocated teaching and learning focused on helping students understand the textbook knowledge they teach. Phrases such as 'for science to be taught properly for students to understand', and 'for it to be understood' characterise their narratives about good teaching and learning of science. For them, understanding means comprehending or making sense of textbook knowledge. They described teaching and learning approaches that they believe may facilitate students' understanding.

Most commonly, they espoused the use of laboratory activities in teaching and learning to foster understanding. Unlike the other teachers, John and Alex linked student-led activities with promoting understanding. John remarked: 'When any science topic is taught practically, I [John] believe students can understand properly but if they just read and memorise from books it becomes difficult…they do not easily understand'. Likewise, Alex clarified:

> For example, for me as a physics teacher [?], in my view this, this science for it to be taught properly [?], for a student to understand when taught [?]… Science as a science to be taught effectively, we should teach a little bit of theory, but we should strongly emphasise on practicals.

Further, they advocated giving familiar examples and illustrations to help students grasp and make sense of textbook knowledge. John described:

> When you just tell them that this plant has network venation, the other one has parallel venation or this one has scattered vascular bundles and the other one has vascular bundles arranged in the ring! For sure, it becomes difficult for them to grasp! … but when you come with sugar cane or maize or bean leaves and you show them, I found they understand.

In addition, they espoused helping students to link the content knowledge they learn in class to concrete reality in which they can apply the knowledge. Alex felt that teachers should show how students can apply the knowledge they acquire in class:

> In science, we must show students a reality. Let them see aaah! this thing, this is how we can apply because today they are here but tomorrow they should do jobs that require this kind of knowledge […] even in the examination, they will be confident.

Another technique that surfaced from teachers' narratives was organising and sequencing lesson presentation in a way that allows students to make sense of the subject content. John illustrated:

> For students to understand, I even change the sequence of the topics. For example, in Form III the first topic is usually 'chemical equations'. I usually don't teach that until I have taught 'acids, bases and salts'. Because when I am teaching chemical equations, I tell students 'when you take one element and combine with another, you get a compound. That compound can be acid, base or salt'. But students do not understand what acid or base or salt is unless they have been taught first. Therefore, when I start teaching chemical equation first, they don't understand but if they have been taught acids, bases and salts, they understand more. Even in electrolysis….

Lastly, teachers espoused teaching and learning strategies that optimise students' participation, including discussions and question-and-answer techniques. They believe that when learners are engaged in learning, they are better able to make sense of the material. Alex illustrated:

> I will tell them to go and discuss. I give them like few points and assign them into groups. Within groups, they make intensive discussions and when I come to class next day, they present and thereafter members of the entire class add some points and ask questions and challenge the group. It becomes a debate and battle where people compete. And thereafter I ask them to cool and sit down! Then I criticise them, tell them 'you could do like this or that', then I wipe the chalkboard and teach them what they are supposed to know… I write notes for them to copy and when I leave discussions continues, 'you made a mistake, you lied' and things like that.

The lesson extract above has three segments. First, a teacher created a space to engage students by assigning discussion tasks. The teacher also provided hints while the students formed groups. Then, the teacher left, and the students took the entire responsibility for discussions, presentation and responding to questions. Lastly, the teacher returned, initially overseeing the presentation, but increasingly taking over the platform. On retaking the platform, the teacher pinpointed and arbitrated what was correct and incorrect about the students' responses. This culminated in delivering the prescribed content and writing notes for the students to copy.

One interesting view came from John, who believed that computer simulations can facilitate students' understanding of science. However, he remained sceptical about the practicality of using technology considering the resource constraints in his school:

> If we could have things like computer simulations! It could help a little bit because directly a student could see things. We could simulate those electrons if it is cations or anions when they move to the electrodes or if it is cations when they move to anode or anions when they move to cathode we could simulate that. In that case, students could understand the concept of electrolysis instead of just memorising. But our environment does not allow this.

This suggests that even when teachers hold sophisticated beliefs about teaching and learning, a shortage of resources may constrain them. Therefore, although Alex and John espoused strategies that can foster deeper understanding, they were uncertain as to whether they could enact such sophisticated views of teaching. They listed contextual constraints that could impede them from enacting the ideas they espoused. Alex explained:

> Laboratory equipment are problematic because [?] Like if you want to teach electricity, the equipment for measuring voltage, electricity and other things [?], these should be available for every student or at least two students could share. But sometimes I have 30 students sharing three or four apparatuses…it's difficult, others just watch without doing it themselves.

This suggests that, despite being aware of interactive teaching approaches that could deepen students' learning, the teachers considered such models of teaching to be impractical in their schools. Closely connected to resource constraints is the overcrowding of classrooms. Alex felt that teachers resort to transmissive teaching because science practical work is difficult to carry out in classrooms that are overcrowded:

> Because currently we use this what? (pause) Transmission approach because students are many therefore practicals are difficult to what? To implement but I think science should be learned more practically.

These accounts illustrate that science teachers may hold sophisticated understanding of teaching and learning, yet they limit their teaching to conveying knowledge. In other words, their perceptions of feasible teaching practices influence the beliefs they enact during actual teaching (Al-Amoush et al., 2013). In chapter 6, I discuss in more detail the way that contextual constraints shape teachers' beliefs.

Overall, John and Alex perceive teaching as facilitating students' understanding of the textbook knowledge that teachers deliver. They view learning science as comprehending textbook knowledge. These teachers advocate strategies to promote students' understanding, such as practical activities, giving students familiar examples and connecting knowledge to real-life contexts and sequencing it in ways that the students can comprehend. Further, teachers highlighted challenges that suggests that having them hold beliefs congruent with the teaching reforms is not a 'panacea'. When classroom conditions are not favourable to allow the teachers to enact their beliefs about good science teaching, changes aimed at improving science teaching are likely to remain unrealised.

Research in other contexts shows that teachers view teaching as creating a space and facilitating activities for students to develop their understanding (Boulton-Lewis et al., 2001; Taylor and Booth, 2015). In contrast to teachers in other contexts, John and Alex exhibited a narrow view of 'students' understanding'. This is because they excluded students' prior knowledge from their accounts of teaching. I interpret this as a lack of recognition of the role of students' prior experiences in knowledge building (Levitt, 2002; Paakkari et al., 2011). Students' prior knowledge is often recognised as a starting point for building deeper understanding (Taylor and Booth, 2015). Perhaps teachers do not recognise the need to consider students' prior knowledge because they believe that legitimate science must be textbook-based.

5.2.5 Section summary

Overall, all six teachers believe that teaching is about conveying textbook knowledge for students to acquire and reproduce during exams. Consistently, they perceive learning science as receiving and accumulating knowledge for later reproduction. Moreover, three teachers view teaching as engaging students in learning activities, in addition to their mainstream beliefs in teaching as conveying knowledge. These three teachers espoused supplementing teacher talk with student activities, the aim being to persuade students to accept scientific facts. Further, two teachers described teaching as helping students understand the textbook knowledge the teachers deliver. Consistently, they view learning science as comprehending textbook knowledge. To promote understanding, they advocate student activities, giving students familiar examples, connecting knowledge to real-life contexts and sequencing content in ways that students can comprehend.

All four categories of teachers' beliefs about teaching and learning fall within the frameworks I adopted. Based on Kember (1997), beliefs about teaching as conveying knowledge for students to acquire and reproduce during exams fall under a 'teacher-centred' view of teaching. Under this view, a teacher dispenses knowledge while students receive it. Students revise, memorise, and reproduce knowledge on demand, particularly during exams. These features symbolise teacher-centred teaching (Magnusson et al., 1999). Conversely, a belief in teaching as promoting students' understanding is in accord with a 'learner-centred' view of teaching and learning (Kember, 1997). The two teachers in this study who hold this belief advocate helping students to make sense of textbook knowledge.

In contrast to studies in other contexts (see Boulton-Lewis et al., 2001; Kember and Kwan, 2000; Park et al., 2010), a belief in teaching as facilitating students' understanding represents the most advanced view of teaching exhibited by two of the six teachers in this study. Research in other contexts shows that the most sophisticated belief about teaching and learning is the belief in 'teaching as conceptual change' with a focus on transforming students' thinking (Kember, 1997; Boulton-Lewis et al., 2001). Teaching as a conceptual change was not evident in this study. In what follows, I discuss the links between teachers' beliefs about science knowledge with their beliefs about teaching and learning.

5.3 Teachers' beliefs: Consistencies and inconsistencies

In this section, I highlight how teachers' beliefs about scientific knowledge might be implicated in their beliefs about the teaching and learning of science. Firstly, teachers view scientific knowledge primarily as a body of facts that are verified through experimentation and testing. Facts are in the field of external authority embodied in teachers and textbooks. Thus, for teachers, the purpose of teaching is exposing students to 'scientific truths' that they are expected to accumulate. Teaching is about propagating knowledge in unaltered forms as presented in the key textbooks and in teachers' knowledge. Accordingly, learning science is about building a knowledge repository of scientific facts.

Secondly, the belief that scientific knowledge is absolute appears to be consistent with views of teaching and learning that de-emphasise the construction of scientific knowledge by students through the authentic exploration of scientific phenomena that queries assumptions and findings. Further, teachers' perceptions of teaching science suggest that they assign little value to teaching and learning processes that promote reflection, imagination and making sense of scientific knowledge. In other words, there is little feasibility in questioning, critiquing, and reconstructing scientific 'truths', consistent with teachers' belief in the factuality of scientific knowledge.

Thirdly, teachers' preference to sticking to textbook knowledge reflects the belief that scientific knowledge in textbooks is stable and definitive. This advances a view that science textbooks provide fixed knowledge with less emphasis on how that knowledge arises through experimentation, critique and extension. Teachers in this study, therefore, expect students to stick to textbook knowledge. They assume that the students begin with empty minds before engaging with textbook knowledge and comprehend it uniformly on engaging with it. Consequently, they expect uniformity in the way that students articulate scientific explanations. In addition, they see the ability to recall and reproduce exact replicas of textbook knowledge as a standard of learning. For them, ideas are worthy only when aligned with textbook content (Russ et al., 2009).

Fourthly, the belief that scientific questions and problems have simple clear-cut wrong or right answers appears to be consistent with teachers' preference to seeking single answers when they ask questions during teaching and learning. The teachers espoused encouraging students to memorise faithful copies of scientific explanations, with the intention of encouraging the students to reproduce one correct answer for a given question. This reflects their conceptions of scientific questions or problems as having simple correspondent relationships.

Further, the view that scientific knowledge is organised in discrete bits and pieces is consistent with teachers' conception of the standard of learning as the ability to recite a list of facts. Teachers seem to find it difficult to connect concepts both within subjects and between subjects to explain complex relationships and to develop deeper student understanding of a 'meaningful whole'. In short, teachers' conception of learning as the memorising of discrete facts, instead of the development of holistic understanding, coincides with their view of scientific knowledge as a body of isolated facts.

The belief that scientific knowledge arises from empirical observation of natural phenomena via senses of perception is consistent with teachers' espousal of teaching and learning as engaging students in activities. The link between these two sets of beliefs is that, through activities, students should be able to experience science directly using their own senses of perception. The students become convinced to believe scientific truths when they gain first-hand experiences. In other words, student activities are means to justify scientific truths. A simple illustration may be when I asked teachers how they made the students know that gravity exists and Alex responded by saying that 'students could see gravity by throwing an object which falls to the ground'. Related questions using concepts of genes, atoms, elements, up-thrust and electrons prompted similar responses in which teachers connected their epistemology of science, teaching and learning.

Lastly, the conception of science as tentative knowledge, held by two teachers, was not evident in their beliefs about teaching and learning. This is because their perception of teaching and learning as 'facilitating students understanding' does not include critiquing, interrogating, and reconstructing textbook knowledge. Their notion of 'understanding' is that of making uniform meaning from the textbook knowledge. Thus, the 'real' belief of these two teachers is that of science as a fixed body of knowledge.

Overall, the science teachers espoused congruent beliefs about science knowledge, teaching and learning. They hold naïve beliefs about science, teacher-centred beliefs about teaching and cumulative beliefs about learning (Kember, 1997; Schommer, 1990). This is largely aligned with what Tsai (2002) described as nested epistemologies. I refer to this 'nest' of beliefs as 'traditional beliefs' in contrast to 'constructivist beliefs' about science knowledge, teaching and learning. In chapter

6, I discuss the social, cultural and contextual factors that may have contributed to the formation of teachers' beliefs.

Chapter 6: Formation of Science Teachers' Beliefs

6.0 Introduction

This chapter discusses how socio-cultural and contextual factors might have contributed to the formation of teachers' beliefs about scientific knowledge, teaching and learning. Generally, I argue that social, cultural, and contextual conditions in schools might have shaped the formation of teachers' beliefs and the way teachers enact these during the actual teaching. These are thematically organised and discussed in the next sections.

6.1 Childhood experiences

Teachers' beliefs about students and ultimately the way they interact with students during teaching and learning may reflect 'habits of thoughts and conducts' inculcated during childhood. I asked teachers to visualise and recollect their childhood experiences. During childhood, the teachers experienced childrearing practices that encouraged them to internalise hierarchical adult–child relationships signified by suppositional adult authority over children. Deman recounted:

> In the family[9] I grew up, there were always people I had to obey what they say. They say they have seen the sun before I did, so they know better than I do. Even when you are born twins, they say the one who saw the sun first is always a brother or sister to the other, so we must obey them.

Apparently, the teachers grew up in a social setting with hierarchically ordered family members according to age and authority. As Deman indicated, children were obliged to obey their adult relatives who had authority over them. Age justified hierarchy and authority. Further, while growing up, the teachers were encouraged to internalise both social hierarchies and socially acceptable behaviours as they interacted with relatives of different ages. This included being submissive and receptive of adult authority and orders. Nuru expounded:

> When I was young, I remember I was required to obey my parents, my elder sisters and brothers… Therefore, I had to listen to them in everything. In

[9] Deman means the community or an extended African family that includes grandparents, uncles and aunts.

> anything [?] when my parents, brother or sister says it's like this, I wouldn't doubt.

The teachers' self-image as authority figures entitling them to determine what and how students should learn appears to correspond to their experiences of hierarchical adult–child relationships. It seems that the broader cultural context places children in subordinate positions relative to adults. Their culture has put children in a position where they have no choice regarding what and how they should learn. Teachers would not traditionally expect students, as their subordinates, to contribute ideas as legitimate knowledge. The cultural rank of teachers legitimatises them to choose 'what is best' for students and force them to submissively accept instead of questioning or negotiating, as envisioned in the curriculum.

In their upbringing, the teachers experienced, internalised and legitimised the external control that adults[10] exercised over them. In this case, external control involved children relying on adults for their everyday decisions, choices, and conduct. Adults prescribed and imposed what they presumed was right or wrong, and expected the children to comply submissively. Alfred substantiated:

> When you want to do anything, you must ask mum, or dad, or any elder. You must get their consent. You can't just decide alone, today I am going to do this. Like even when you want to go and play with your friends, you can't just rush out, your parents must have allowed you.

Adults are culturally entitled to arbitrate choices for children because such choices require information and may have detrimental consequences for the children. Only adults can fully assess and anticipate the consequence of choices because they are more informed. For example, adults can assess types of friends, time, and the

[10] Adults in this context include one's parents, siblings, and relatives. Even when children are twins, one is always older than the other.

consequences of such choice. This superior expertise and judgement culturally legitimatises adults to decide for their children. For example, adults set norms and limits on what children can or cannot question. Teachers recounted their memories of things they could or could not inquire about. It was acceptable to question ‘ordinary things’ generally considered desirable for children to know:

> We were to think carefully. We could ask ordinary things like you want to know names of animals or plants… But, you can’t question about the decision, or actions or behaviours of your parent (Deman, Interview).

These set norms prohibited children from questioning adults’ decisions and actions, as Nuru exemplified: ‘Like when your dad says you can’t go out today or you’re not allowed to do this or that, you can’t ask why?’ Interrogating adults signified attempts to undermine culturally legitimatised adult authority and a lack of interest in adhering to shared ways of life. Questioning an adult signified disobedience, as Deman explained: ‘I felt like when I ask about that, I am already disobedient. I felt embarrassed for disobeying’.

The hierarchical relationship between parents and children appears to reflect the relationship between teachers and students that the teachers espoused when describing their lessons. For example, the norms about what children could inquire or simply assimilate appear to coincide with teachers’ preference for requiring students to accept scientific truths unquestioningly (see section 5.1.2). Therefore, the deeper cultural norms that set limits regarding what children can ask may prevent teachers from allowing students to interrogate and critique scientific knowledge.

Teachers recounted various strategies that parents use to encourage their children to internalise socially desirable behaviours. They ubiquitously acknowledged having themselves experienced punishment, verbal threats and similar fear-inducing childrearing practices. Alfred explained:

> Sometimes even when you are accused of doing something wrong and you certainly know you didn't, you couldn't object and argue with your parent. You would certainly ignite more anger if you did that. Sometimes, you could be slapped for something that wasn't your fault really! For me I just remained silent, when the anger is gone, he is calm, then I could politely say, 'I wasn't the one who did that'.

Notable in Alfred's accounts are memories of childrearing practices that inculcated in children a sense of submissiveness, fear and obedience. Two forms of punishments surfaced from teachers' recollections. First, parents disciplined children to learn socially desirable conduct and to halt misconduct:

> My mum used to beat me when I let cattle destroy crops in the neighbourhoods... We used to look after cattle but sometimes we ended up playing, only to find cattle have destroyed other peoples' crops (John, Interview).

Generally, the teachers viewed this form of punishment positively. They believe that the intention was to inculcate desirable behaviours in them. They felt that they deserved punishment for wrongdoings:

> It is okay! When you do something wrong, you deserve it. It is a kind of reminder that you should not repeat that (Alex, Interview).

However, participants were critical of careless beating, even though they perceived punishment as taking responsibility for one's mistakes. Florian articulated his childhood frustrations:

> We had many problems… Dad beat us; life was very difficult. Dad became very harsh on us, and mum. My older sisters chose to get married when they finish primary, just to escape from everyday beating. … When dad came home, he was often drunk; he beat us with our mum, it was chaotic.

Similarly, Nuru criticised her parents for being too harsh: 'Often you will find parents are too harsh, they mistreat their children. They think by being punitive, children will be obedient… children will be submissive'.

Punishment and similar fear-inducing childrearing strategies used to reinforce adult authority, obedience, and acculturation of socially desirable behaviours at home dovetail with widely treasured (and practised) corporal punishments in schools. It may be that the teachers cherish and use the same strategies because they experienced these during their own upbringing. This may be students' source of fear, submissiveness and lack of confidence to talk in class.

Although I have focused on the childhood experiences of the teachers, it is likely that the students had similar experiences, considering that they are growing up in a similar social context. Therefore, I have presumed that both teachers and students have been socialised into structures that emphasise adult authority and dominance. When teachers and students bring these 'habits of thoughts' into the classroom, it may shape the way they think, act and interact. Teachers, for example, may restrict students in terms of what they can or cannot question, consistent with the teachers' childhood experiences in which questioning adults was circumscribed. Consequently, the teachers may think that the knowledge they teach is unquestionable, but simply given and received. Equally, if students grow up in contexts in which questioning knowledge is not encouraged, they may be reluctant to interrogate knowledge in class. Therefore, both teachers and students may have constructed perceptions of teaching and learning as the delivering and acquiring of knowledge, consistent with their own childhood experiences.

6.2 Schooling and training experiences

Beliefs about science, teaching and learning held by teachers appear to reflect their own experiences as learners. The type of teaching they experienced and how they themselves learned science as secondary school students and student teachers is implicated in their understanding of teaching and learning science. In the following subsections, I discuss the influence of previous schooling and training.

6.2.1 Teaching of their former teachers

I asked participants to visualise and describe the teaching practices of their favourite former school and college tutors. When recounting the teaching of their former teachers, participants connected their own teaching with the teaching they received, as Nuru remarked: ‘So, when I am teaching that topic [the topic of locomotion] I usually reflect more of that tutor’. Two major teaching orientations emerged from the accounts of teaching they experienced during secondary schooling.

Most notable in their recollections was transmissive teaching by conveying knowledge. Participants complimented their former teachers who had shown outstanding mastery of the subject content. Complimenting her Biology teacher, Nuru said:

> Eeeh! First, she was showing she knows her subject. The way she was flowing materials, she was not even using notes. All the materials were coming from her head.

Nuru’s recount suggests that her Biology teacher was highly knowledgeable because she had a good grasp of Biology knowledge, which she demonstrated by not referring to her lesson notes when teaching. Participants applauded their former schoolteachers for being talented at delivering lessons, which were characterised by teacher talk, explaining concepts, defining scientific vocabulary and writing notes. They admired well-planned and systematically delivered lessons. For example, Alfred characterised his teachers as serious and authoritative:

> What he was doing [?] he wasn’t joking, he was very serious, when he enters, the class becomes silent. He had a very good plan in teaching. The big thing he does was to write notes for us first before he teaches. He must write notes first. He could write until the chalkboard is full, then he starts explaining. So, there he was not only teaching Physics but he was also explaining and underlining some of the important vocabularies… he explained word by word… and he reaches on the calculation, he didn’t write it… you do it together first. He wiped it out and you do it repeatedly. Then he writes all the calculations and you copy.

Likewise, Nuru explained:

> Eee hehe! (laughter) She was just flowing; flowing, flowing, flowing…She was coming to teach with empty hands. She flows everything from her head. We even wondered how she managed to organise all the materials in her head. And the way she was teaching with swaggers!

Well-planned and systematically delivered lessons were seen as easy to follow:

> When he writes, you know exactly when he moves from here, he goes there and from there he goes [?], it becomes easy to follow systematically and after that you copy everything, he allows us to copy (Alfred, Interview).

Overall, participants' aspiration for teachers who are effective at content delivery is in accord with their understanding of teaching as conveying knowledge (see section 5.2.1). Conversely, participants were critical of former teachers who had not shown mastery of the subject content. Alfred described a Physics teacher he disliked:

> That teacher was not! I didn't admire him at all…He didn't know things [i.e. physics], like these calculations he was copying straight from the book. So, you will find he copied only one example from a book, he couldn't even make one example of his own.

They felt that some of their college tutors were too rigid and authoritative. These tutors were uncaring, and less open to alternative views. John expressed his feelings:

> Tutors were very rigid for the issues they taught… they assumed they were the ones who knew everything. They are the experts with final say on the things they taught without considering that we had a variety of experiences… but they were the ones who compose exams and decide whether you pass or not. If you don't abide by them, you are looking for troubles.

Likewise, Nuru described her college tutor as follows:

> She was not motivating at all. When she entered the class, hee! She never smiled to anyone. I remember her very well... She never entertained anybody, whether you understand or not it's up to you.

Interestingly, some participants ended up emulating the behaviours they disliked, including being authoritative. Nuru implied this when she responded to a question about her openness to interrogation by students. She said: 'Eeeh! No, it can't happen. Honestly! A student arguing with me? Haa!…'. Perhaps authoritative pedagogic practice is a cultural legacy that teachers implement unconsciously. Overall, mastery of subject matter and well-organised lessons are seen by participants as important attributes that define good teachers. This indicates a view of teachers as repositories and dispensers of expert knowledge (Akyeampong and Stephens, 2000).

Teaching and learning in teacher education colleges tend to replicate practices found in secondary schools. Participants indicated that college teaching largely involves lecturing and dictating notes that the student teachers copy. Much of this reflects what they experienced when in secondary school. John described the way his college tutor taught:

> On entering the class, he [the tutor] started explaining while writing down key points on the chalkboard… the way he explained neurones…he started what's a neurone? A neurone is the …, a synapse is … they communicate through neurotransmitters … he also wrote those terms. It was easy to follow and you come out of the lecture with something in your head. He was good in explaining… it's a talent anyway.

Alex shared similar experiences:

> First, the way they taught like in the lecture hall, a tutor talked and talked… reading notes loudly and you [the students] copy... After one hour, you get out. That means it was a tutor only who [?] it means they just transmitted knowledge to students.

Further, participants recounted experiences of occasionally participating in activities. The applauded some of their former teachers for occasionally employing teacher demonstrations, question-answers and investigative techniques as Deman recounted:

> He was teaching volumetric analysis… those titrations, I remember. He taught us in class first… then, we went to the laboratory, he showed us in reality; You take this volume, you subtract that, those moles, so, he was showing us those things, the way he showed us in class when we did those calculations in that table. He showed us this table [?] I don't know what, pilot! This is the pilot; you do this one like this. So, he was going along with the theory he taught in class… this… made his teaching interesting to me.

Likewise, John acknowledged that his teacher was using different strategies for engaging students. He said ‘For example, he gave us tasks to go and discuss after he has taught. He also engaged us in competition when answering questions on the lessons he had already taught. I really liked that competitive approach’.

Teaching through activities is also evident in participants’ recounts of their best college tutors. Participants recalled interesting moments of watching tutor demonstrations and answering questions that tutors asked during the lectures. They were assigned group tasks, presentations and practical work. Nuru had the most interesting experiences with a college tutor who had used her own body to show the location of different bones and joints:

> That Form III topics on movement and locomotion [?] and those joints. I remember [?], the way she was teaching; when she mentions a joint she touches it, she touches the joints of her hands. I mean that thing of showing us which joint is where… where is the pelvic girdle… she was showing us where every joint is located.

While teachers recounted positive experiences with activities, a deeper analysis of the pedagogic approach may reveal that the direct teaching of subject content always preceded students’ engagement in activities. This means that teachers prioritised content delivery over student activities. Deman experienced a pedagogic approach in which a teacher delivered content and supplemented this with a demonstration of the concept of the mole and titration procedures. The remark ‘he was showing us those things’ suggests that a teacher performed the activity and students observed. Her account therefore indicates that a teacher dominated the activity and that student engagement was minimal.

The overall picture is that the type of teaching that participants experienced during their own schooling and training reflects the way they understand and describe their own teaching. They described the teaching of their former teachers as lecturing, dictating notes, asking questions, and engaging students in activities. This reflects much of what they said when they described their own teaching as conveying knowledge for students to acquire.

Other relevant experiences included teaching that emphasised mainstream knowledge sources. Teachers recounted memories of college tutors who had precisely prescribed specific textbooks that student teachers had to read to pass their exams or to write essays. Alfred explained:

> There was another tutor called [-], for that one when you present something different from what he gave, you can't reconcile, you will be in trouble. So, when we were learning we knew this one [tutor] want this! And he even provided references; 'go and take it [knowledge/content] from here, take it from there', if you take it from a different book, he never accepts.

Likewise, John expressed similar concerns about tutors who had rejected student teachers' ideas that had differed from those the tutor had taught:

> There are tutors who don't accept anything else other than what they taught. But, they are not supposed to be like that because in college, some students are coming from work… they have been teaching while others are directly from schools. Each one has some knowledge.

These accounts suggest that college tutors tend to be rigid in terms of what they consider legitimate knowledge. They discourage and reject ideas from sources of knowledge other than those they prescribe. This resonates with the findings of Akyeampong (2017), who observed that hierarchical tutor–trainee relationships constrain the learning of learner-centred pedagogy shaped by insights from real classroom contexts. Such relationships compel student teachers to unquestionably assimilate and implement tutors' prescriptive practices without reflecting on their practicability for diverse classroom contexts. In the context of college assessment, student teachers who deviate from this norm risk being penalised when their work is graded. Possibly, tutors see the content in mandated textbooks as the most legitimate knowledge that student teachers should acquire. Perhaps, during their own schooling and training, tutors had also been socialised into this way of viewing knowledge.

Teacher education that emphasises authorised textbooks as the sole legitimate sources of knowledge, without exposing student teachers to multiple accounts of the same scientific phenomena, may reinforce narrow conceptions of scientific knowledge. Similarly, the assessment that the teachers experienced during their own education might have reinforced their conceptions of scientific knowledge as something that is codified in textbooks.

6.2.2 Experiences of science practical work

I explored participants' experiences with practical work, which is an important instructional strategy for learning and modelling scientific inquiry. As with other hands-on learning activities, practical work is an opportunity to observe something interesting, as Deman remarked: 'I remember when we study Biology; we must see something very interesting. So, that made aaah!' However, a remarkable feature in their accounts is how their former teachers were accustomed to specifying recipe-like procedures that students had to follow when conducting practical work. Nuru recounted: 'Eeeh when he assigned group practicals, he did the first practical himself…he was showing us systematically…. the rest we did it ourselves'.

While participants admired their former teachers for being resourceful in providing detailed guidance for practical work, they disliked those who had assigned open-ended laboratory tasks by delegating substantial responsibility to students. Participants objected to approaches to teaching that had heightened their mental and physical engagement in learning beyond watching 'teacher shows'. For example, Nuru criticised the way her A-level teacher had handled a chemistry practical:

> Like in practical she didn't know…When she came, she just gave materials and left us alone. She would say 'it's up to you if you didn't learn in tuition… do it and write a report'. She destroyed our future. Therefore, at the end of the day, you do it the way you think and send a report to her. We couldn't learn anything. If one of us had an idea, we all copy the same idea and submit… Maybe she just didn't want to explain it to us. She just let us wonder without knowing what to do… she assumed we could sort it out ourselves.

As Nuru clearly articulated, participants were critical of their own teachers who had assigned practical work without detailed guidance on what they had to do. This suggests that participants are accustomed to the type of instructions in which a teacher delineates most of what is learned. Although assigning totally unguided tasks may not be advisable because this can mentally strain students (Kirschner et al., 2006), most of the complaints recounted by participants seem to emanate from their expectations that teachers should be telling everything. Florian explained how practical work had been organised at the college:

> When we entered the laboratory… everything has been prepared for us. We simply followed the procedures stipulated in the practical manual. I mean what we were required to do and how to do it.

Likewise, Deman illustrated:

> For example, when we did practicals in organic Chemistry. We were to connect equipment and prepare standard solutions... but when we go to labs, this wasn't the case… for example those standard solutions! They were already prepared; we were just told standard solutions are there! Our task was to just take the standard solution and mix with reagents.

These responses suggest that their tutors provided student teachers with practical manuals and the required laboratory reagents and supplies. Practical tasks therefore involved technically following the prescribed procedures, limiting the range of inquiry skills that student teachers could practise. This appears to have influenced their confidence in organising and conducting practical work in their current classrooms. Alex explained:

> I think that has no value to us! Because our task was just to follow those procedures, you will find, we were doing practicals but we couldn't realise the

> value of such practicals in our teaching careers.

Likewise, John illustrated how he struggled to teach practical work because of his weak background:

> As teachers, we are required to prepare and teach practicals… But the way we were taught at that time… I couldn't prepare any practicals at all! I had to ask another teacher to teach me how to prepare practicals. Because I couldn't, we weren't taught on how to prepare practicals.

These accounts suggest gaps in teacher education that influence teaching in schools. Further, the way teachers described practical work in schools (see section 5.2.3) reflects their descriptions of the practical work they experienced during their own schooling and training. Consistent with their school and college experiences, teachers advocated organising practical work by clearly delineating the procedures that students must follow to arrive at the expected results, which must replicate the established body of knowledge. In short, teachers' background experiences coincide with their understanding of the best ways to organise inquiry learning in their classrooms.

6.2.3 Learning experiences

Learning strategies that had worked effectively for the teachers when they had been students appear to have shaped their understanding of learning and the type of learning they try to promote in their classrooms. In schools and colleges, learning involves listening to lectures, copying, and memorising notes, and taking part in occasional hands-on activities. During their own schooling, the teachers had spent many hours memorising lesson notes they had copied in class. Nuru explained:

> You know you can perform while you are not knowledgeable. You can pass but only through rote learning. You have just crammed. I was using too much energy to understand things. I just crammed in certain ways. Those theories, practicals, one practical that is all. But, it is not that I was competent, that I have mastered the subject matter. Aaaah! That thing, I was not competent, honestly. Especially on practicals, I was not competent at all. But, we just progressed blindly. Those theories, two to three calculations, I just crammed. If I find it in the exams, then I answer. Therefore, I found myself going through

> A-level. Yes, I passed but….

According to John, learning ‘was mostly swallowing, swallowing! The system was mainly that of swallowing’. Likewise, Florian recounted how he strived to achieve this vision of successful learning:

> So, I continued to struggle personally and luckily, I succeeded to pass my examination because I scored Bs in all science subjects; Physics, Chemistry, Biology and Mathematics and… I was selected to join Form V, but this was after many nights and weekends of going through teachers’ notes.

These recounts suggest that the desire to pass public exams had motivated participants’ learning. Therefore, the priority had been mainly on acquiring the prescribed subject knowledge that they needed to pass these exams. Using the phrases ‘just crammed’, ‘mostly swallowing’ and ‘going through’, participants portrayed how they endeavoured memorising prescribed content. Although participants seemed to appreciate the value of deeper understanding, such holistic learning had not been their priority because eventually passing exams and access to further education defined successful learning. In this case, memorisation was effective for acquiring the tested content, although it resulted in superficial learning.

College education further reinforced these school experiences. Participants indicated that their former college tutors had demanded student teachers to reproduce copies of lesson notes or of the textbooks they prescribed. Tutors enforced this demand through assessment practices by rewarding a single or fixed pattern of answers instead of rewarding broader understanding and reasoning. Alfred explained:

> Often, tutors didn’t entertain students explaining concepts in their own words. For example, I had one tutor (pause) he wanted us to explain everything exactly the same way he taught. We had to go exactly the way he said... They didn’t want students to diverge from what they said at all.

John illustrated:

> For example, in Chemistry, which involves calculation, you could find what the tutor considered a correct is only the final answer. That means even when you make a mistake in the final arithmetic of dividing [?] let's say 50/20 and you wrote 100, you lose all the marks even when the formula and procedures were correct. They were marking the final answers, something that wasn't good.

To cope with the exam system that compelled them to reproduce subject content, participants developed various strategies that optimised their chances of success. They made sure they copied notes during lectures, memorised and practised answering past exam questions, which tutors often repeated. Nuru explained why they had to copy notes:

> But, if you don't copy everything how are you going to pass their tests? They always ask things from their lecture notes and they expect us to explain things the same way they did to us.

Deman explained how they practised answering past exam questions in preparation for upcoming exams:

> When the term began, we photocopied as many past papers as possible. Each time a test is announced, we practised as many questions as possible. You could hear people saying, 'what are the possible, who has the possible, it's possible, possible, possible!' that's how we passed.

The words 'possible, possible' refer to the past exam questions that could possibly be repeated in the forthcoming examination. This means they had developed an intuitive ability to predict future exam questions as Florian explained:

> It depends on the tutor, for old tutors we had stories from our colleagues. They told us how different tutors behaved, if they often repeat questions on the test or not which most did.

These recounts suggest that beliefs in learning through memorisation with a focus on passing exams have their foundation in the teachers' own schooling and training experiences. These background experiences appear to shape their perceptions of learner-centred approaches that emphasise deeper learning. Nuru explained:

> Now they want us to engage students in doing activities [?] what? What? You are just bothering yourself. People pass (pause) people get A's even by solving past papers and swallowing notes, why all nuisance?

This accords with the proposition that teachers' past experiences of successful learning through memorisation influence how they think about teaching and learning (Mansour, 2009). Given that learning through memorisation worked well for these teachers, it is not difficult to see why they subscribe to the idea of learning science as the accumulating and storing of knowledge for use in exams.

To sum up, teachers' recounts suggest that their own experiences of being taught and assessed are reflected in their own instructional approaches, and might account for their preference for teaching practices geared at helping students pass exams. Further, their background experiences of assessment designed to prompt and reward single final answers, match their views of scientific problems as having right or wrong answers, and closely correspond to their understanding of scientific inquiry as a stepwise process of seeking 'correct' answers known beforehand. The teachers not only admired the teaching practices of their own teachers, but also adopted elements of these in their own practices, as discussed next.

6.2.4 Modelling their former teachers

I explored teachers' perceived influence of their background experiences on their current teaching practices. Generally, they were unconscious of taking on the teaching of their former schoolteachers. For example, after reflecting, Nuru remarked: 'For sure I have realised now, that's absolutely true! The way I teach is same way my teachers were teaching us at school'. Then, she went on to substantiate:

> For example, if there is something I didn't understand how to teach, I simply reflect the way my teachers taught (pause) this concept I don't have an idea how to teach, how did madam [name] teach? I even have my secondary school notebooks… I look at them, how they taught.

In her account, Nuru identified elements of her own teaching that correspond to those of her former teachers. Nuru adopted teaching strategies and teaching materials, including her own lesson notes, from her former teachers. John imitated explaining and writing notes:

> If I take O-level as a reference point. I was interested in teaching like my tuition class teacher… he really impressed me with the way he teaches… He had a style of teaching while writing notes. He explains but at the same time, he writes notes. It was very easy to follow on and copy notes.

Teachers may value and adopt the practices of their own teachers, especially if these contributed to successful learning (Eick and Reed, 2002). When it comes to the practices of their college tutors, participants were readily conscious in acknowledging the practices they adopted. Alex explained:

> I do the same… sometimes when I enter the class I take my notebook pap! Then I read and explain… I write key words. It goes like that and at the end, I tell them, go and read this or that book.

All the teachers gave similar accounts of the teaching techniques they had adopted from their former teachers. These mainly involved explaining, deriving formulas, showing how to solve calculations, and writing notes on the chalkboard. Most of these symbolised a transmissive teaching that the participants themselves espoused when describing their ideal lessons.

Although they were doing so unconsciously, the teachers generally held unshakeable devotions to the teaching strategies of their former teachers. However, when prompted, they admitted using some of the practices they had experienced during their own schooling and training. This apparently unconscious taking on of the practices of their own teachers suggests that their own background experiences are influencing their current teaching in ways that they do not fully understand.

6.3 School norms and general expectations

I explored teachers' perceptions about how students, parents and school administrators expected them to teach. I found that the teachers seek to align their teaching practices with the norms and expectations inherent in the school context.

In this way, such norms and expectations shape the teachers' beliefs. I have grouped these into the expectations of students, parents, and administrators, as presented next.

6.3.1 Students' expectations

The teachers believe that students expect them to deliver knowledge when teaching. Mastery and delivery of subject content are core attributes of good teachers as Nuru explained: 'I think they [students] expect me to give them knowledge… before even going to the class, I make sure I have the knowledge and students also get it'. Similarly, Deman said: 'They expect me to give them knowledge which will later enable them to pass their examinations'. John expounded: 'If I complete teaching the syllabus the way it is required, students will be happy that I performed my duty'.

Likewise, Florian delineated in concrete terms how students expect teachers to teach:

> When you enter the class, they expect you to stand in front of the class and teach them… you explain they write, you write notes for them on the chalkboard, they copy and you leave. That's what they want us to do... I think that's how they experienced teaching from primary school.

These accounts suggest that teachers represent an important source of knowledge in the classroom. Teaching in which a teacher stands before the class and verbally conveys knowledge while students listen and copy lesson notes into their notebooks is a transmissive type of teaching (Akyeampong et al., 2006). As Florian indicated, teachers attribute students' preference for transmissive teaching to previous school experiences. John expounded on this as follows:

> In the past, you may find most students are used to these spoon-feeding methods. The teacher came, explained, and did everything to them… students simply absorbed. That is why students expects me to give them everything.

Students' notion of teacher as a 'highly knowledgeable' person and teaching as 'providing them knowledge' is coherent with the teachers' views of teaching and learning. The teachers' descriptions of their own teaching as 'giving what students are supposed to know' appear to coincide with students' expectations that teachers impart knowledge. Students' expectations dovetail well with the teachers' own schooling experiences.

The high-stakes exam context appears to be a core driver that shapes the idea of successful learning as the acquisition of subject knowledge that students need to pass exams. Teachers indicated that students perceive themselves successful in learning when they have acquired the knowledge they need to pass exams. Perhaps the influence of exams is pervasive because exam results are criteria for admission to further education and work. Alex elaborated:

> They see themselves successful when they perform well in exams and progress to the next levels of education… when they get knowledge that helps them answer their exams.

Likewise, John amplified:

> Mostly they consider passing the examination… when they realise that they are doing well in the examination they know aah! [?] they have mastered. Therefore, when I am teaching something that does not contribute to making them pass, they complained… this teacher is wasting our time.

Connecting exams and further education, Nuru said:

> What do students expect? I see it's simply passing exams. To listen to me, understand and pass the exams... eeeh! It's passing, passing the exams… go to further education and get a job.

Therefore, in addition to conveying knowledge, teachers feel obliged to teach 'examination-taking' skills. They believe that it is important to teach students techniques for framing answers, the aim being to help them pass exams and achieve their idea of successful learning. Alfred elaborated:

> Our friendship with students become stronger when they are in their final year when exams are nearer… you will hear them saying, teacher, give us the

> possible, give us possible… And it's true if students have no idea of the kind of answers expected in the exams it's difficult to make it.

Overall, the teachers believe students expect them to provide the knowledge they need to pass exams. In addition, students expect the teachers to equip them with techniques for identifying and presenting correct answers in the exam. These expectations are consistent with teachers' espousal of teaching as delivering the knowledge students need to acquire to pass exams. Further, students' expectations are largely consistent with parents' expectations, which I discuss next.

6.3.2 Parents' expectations

For parents, learning counts mostly when students pass exams and progress to further education. Alfred explained: 'I can say they consider success in exams and ultimately progress to further education as a key outcome of successful schooling'. In keeping with this idea, parents expect the teachers to equip their children with the knowledge they need to attain high exam grades. Parents' desire to optimise the chances of their children progressing to further education motivates this expectation. Broadly, this indicates an education system in which passing exams serve as a primary indicator of learning proficiency. Nuru clarified what she perceives as parents' expectations:

> They [parents] want their children to pass exams, even myself as a teacher I would wish my students to pass their exams… all that parents know is that when they sent children to school, they expect teachers to give them knowledge and pass them.

Similarly, Deman explained:

> Parents have very big ambitions for their kids. When they bring them to school, they expect their children to be taught and given knowledge so that they can pass their exams and eventually achieve their goals in terms of employment.

Teachers who align their teaching practices with parents' expectations by conveying knowledge are highly admired. When parents recognise teachers for being the best at delivering knowledge, they hire them to provide paid private extra tuition for their children. Therefore, the possibility of earning an extra income through private tutoring motivates the teachers to align their teaching with parents' expectations. Nuru disclosed:

> You will often find that a teacher who effectively delivers knowledge is the one seen as a good teacher. If you know how to flow materials, then parents will approach to ask you to teach tuition classes for their children. Parents' expectation is that the teacher must be the one who gives out materials in a class. They regard such teacher as a good teacher. If you do that, they approach you and say, 'please help my child'.

Although parents rarely visit classes to observe teaching, teachers recognise that parents monitor children's learning by checking notebooks and annual school progress reports. In addition, students may spread the word about talented teachers. Teachers, schools, and parents often protest when students are not progressing well. The teachers reflected on some of these tensions in their accounts:

> When they receive reports showing children' results and they find a child has performed well, they know aaah! My child has been given a test… he/she is performing well. For example, if this month they scored 20 in biology and the following month they improve a little bit, they know my son is progressing well. Therefore, they look at examination results… they may check notebooks to see if a child has written notes (John, Interview).

Likewise, Alfred explained: 'If your school is not doing well in the exams… their kids are not passing exams, or they are behaving inappropriately, parents blame teachers'. Most what parents expect of teachers might be reinforcing conceptions of teaching as transmitting knowledge and learning as passing exams.

6.3.3 Bureaucratic demands

Because examination results have serious implications for students and the school's general status, school administrators tend to support a type of teaching that is geared at enhancing pass rates. Teachers indicated that school administrators view exam scores as a key indicator of successful teaching and learning. They demand that teachers deliver the subject knowledge prescribed in the syllabus, and check the volume and organisation of notes students write. Alfred explained: ‘The most important thing the headmaster or even school owner wants to see is that I have covered a syllabus’. School inspectors also checked teaching by comparing teachers’ lesson plans and students’ notebooks with the syllabus to prove if teachers were teaching the required content. John reflected on such administrative demands:

> Our headmaster, what he wants is high performance, so that the school can build a name… there must be a superior performance to make the school popular. They should know our school for superior performance and students’ discipline.

Expressing similar views about school administrators’ expectations with a focus on private schools, Nuru said:

> In private schools, most often the teacher is the one who provides materials. The teacher who provides materials is the one seen as the best. It’s a problem. Tell me, if you go to a private school and you can’t deliver the materials [knowledge], will they understand you?

Similarly, Deman remarked:

> We teach to cover the syllabus; we are following what the syllabus requires. The syllabus has specific objectives, which I must achieve and at the end of the day, students sit for the exams to determine if those objectives have been what, achieved or not. In most cases, that’s what they expect to see.

Highlighting the importance of providing lesson notes, John said:

> At least you prepare and give them notes on topics they need to know. You give the notes per their level. Then, you assign them questions, which they can answer using those notes, you tell them to read those notes to answer questions.

Teachers believe that students are unable to prepare notes for themselves because their textbooks contain enormous amount of information that the students need to sort through. They presume that students are incapable of working out ‘what they are supposed to know’ from the large amount of ideas contained in textbooks. John illustrated:

> Imagine you are teaching asexual reproduction and you ask students to write notes about it! Will they know what to take and what to leave? There is just a lot of books for them to sort out!

Possibly, the real aim is to promote acquisition of content knowledge through repetitive practice of memorising notes. This is because the teachers also assign questions in the form of exercise or worksheets that students can attempt only after memorising the lesson notes. In addition, this approach allows the teachers to fulfil their administrative obligation to assess students' written notes.

Although teachers expressed a sense of subjection, they are generally in favour of bureaucratic demands that students pass exams. This may be because the school principals reward and sanction teachers based on students' pass rates. Therefore, teachers' views may reflect both merits and demerits of institutional demands. Alfred explained:

> Even when you look at their demands [?] they demand very good things. They are reasonable… they are not bad. If you can fulfil what they demand, it's obvious that students will pass.

The accountability measures were more pervasive at Getamock than Marera. At Getamock, when the national exam board releases exam results, teachers normally convene to discuss the results. Often, low student performance in the national examination jeopardises the teacher's job. Alfred explained:

> If students are not doing well, you will be required to explain yourself by the school principal…what happened here? What happened here? Why is the number of 'A' we expected to get isn't the one we got? Why is the number of 'F' too big? Or sometimes you are just told 'congratulations, keep it up' as this class wasn't good [not bright]. You know a class that is not good is known.

Likewise, John expounded:

> Aaa! That is possible [being dismissed]. It's possible in our private schools. When students' results are released and you have not passed students, they start doubting you… you may find that when his school doesn't perform well, the principal is held responsible; he must explain.

In community schools, the reward system is more formalised because the government sets a specific budget for compensating teachers whose students attain

A or B grades in the national examination. On several occasions, Deman and Nuru explained the initiatives they had been taking to give extra support to students who had appeared likely to attain an A/B grade, which is a requirement for monetary reward. In one interview, Deman disclosed:

> I am sure if I continue teaching like this [drilling] they will perform well in their exams and I will get my 15 As next year… each A is 10,000 shillings and B+ is 5000 while B is 3000, I will have a lot of money if I help them pass their national exams.

These accounts clearly illustrate a school culture in which principals hold teachers accountable for low grades in their respective subjects. Equally, principals reward teachers whose students achieve the expected grades. Under this school culture, it is not surprising to find teachers who are inclined to conceptualise teaching and learning as helping students to pass their exams.

In summary, school administrative structures require teachers to deliver the prescribed content of the syllabus and to prepare students for standardised exams. Further, accountability structures exist, such as crosschecking the content covered against the syllabus. Most importantly, school principals reward and sanction teachers for students' results in the final examination. These bureaucratic demands seem to dovetail with teachers' preference for teaching and learning that is geared at conveying factual knowledge from the mandated textbooks and testing students' ability to recall. Under this circumstance, it may be difficult to see teachers as agents of change even if they support teaching reforms.

6.4 Learner reticence

Teachers testified that attempts to encourage students to participate actively in learning often clash with reactions from students. Students tend to resist teachers' initiatives to engage them in learning. Nuru said: 'Look! When you ask them questions, they feel like you're annoying them […] though they may answer'.

Teachers indicated that their students have developed numerous tactics to circumvent learning activities that required active mental and physical engagement. These varied from passive resistance by ignoring teacher directives or partial compliance to aggressive moves such as protesting to the teacher.

Most notably, students resist teachers' instructions through partial compliance. For example, the teachers indicated that they may assign activities that demand all students to engage actively, but they might instead copy the work of a few students. Florian illustrated: 'You may assign everyone to work independently first and then write a group report but most of them don't… they will submit what two or three people did'. Similarly, John explained:

> For example, when you assign them tasks, you will find answers for the whole class are the same… it means only two or three students did the work, the rest just copied. They are doing nothing, if you assign group activities it's the worst…only a few participate but they will submit answers as if they all discussed…but in reality, only one or two did.

Likewise, Alfred expressed his doubts:

> If you assign them in groups… they are too many and you're supposed to check every group, will they all participate? You find only two of them participate and the rest just copy.

Further, teachers indicated that students often shy away from contributing ideas, asking and answering questions. Students' reticence militates against teachers' attempts to instigate active teaching strategies, thereby limiting classroom interactions. When sharing his experience, John remarked: 'You will find someone knows the answer but he/she does not raise a hand. Many of them are like that'. Likewise, Alfred said:

> I wish they could ask questions before the whole class so that everyone can hear… I mean for the benefit of the whole class but where [?] they always shy away… there is a fear. They have no confidence to stand before others and ask questions.

Alex also explained:

> I would say like 90% wouldn't ask a question or contribute on their will…but even when you call them by names [?] may be few will try but in most cases, you have only two or three talkative guys but the rests will shy away talking.

Teachers expressed varied perspectives on the reasons for students' reticence. They widely believe that students shy away from participating and taking responsibility for their learning because they are accustomed to receiving knowledge from teachers. This means students might have acquired reticent behaviours because of experiences with transmissive teaching during primary schooling. John explained: 'Now this participatory method is not very common to our students […] most of them are used to spoon-feeding. They are not used to learner-centred methods'. Equally, Nuru remarked: 'Why they behave like that? It's because our students are used to this old style [?], the one that teacher knows everything, is the centre (pause) I mean that teacher-centred'.

I interpreted teachers' accounts of students' reticence from two perspectives. Teachers seem to be suggesting that students resist participating in order to avoid physical and mental strain from learning tasks that require them to engage and think actively. At a deeper level, I believe that these students are maintaining physical and cognitive docility consistent with their background learning experiences. This is central to the notion of 'being accustomed to spoon-feeding'. This is likely in the classroom context characterised by lack of a free and safe discursive culture; instead, students fear disrupting lesson flow or fear being embarrassed, ridiculed and laughed at by peers. The classroom culture neither stimulates multiple thoughts nor encourages students to see inferior ideas as productive learning opportunities. In this classroom culture, students feel diffident about exposing their weakness by contributing ideas and are concerned about making mistakes. Alfred explained:

> They feel like embarrassed… they reflect on how others will take them when they stood to ask a question … Some students see as if you are stupid when

> you ask a question that seems known to them. It's like you are not attentive in class when the teacher was teaching or maybe you are a lazy learner.

Teachers explicitly referred to childrearing practices at home as a key contributor to students' reticence. Deman remarked: 'It begins at home, it depends how their parents brought them up'. Cultural values that emphasise hierarchy and submissiveness promote children's reticence, as Nuru explained:

> First, they are supposed to be silent, they are supposed to be obedient to parents and elders. They have been raised under fears and phobias… even just expressing themselves, just expressing a little bit of something they can't.

However, teachers were reluctant to acknowledge how the hierarchical relationship between themselves and students militates against students' eagerness to contribute ideas and interact in class. Teachers often exercise control over students to maintain respect and obedience. When I attempted to explore this, the teachers were resistant to acknowledge their contribution to classroom cultures in which students fear talking. As a proxy to how they act with their students, I asked how the teachers themselves had been treated when they had been students. Some thoughts emerged:

> Our classrooms those days when you question, it's like you are disobedient to a teacher. Other teachers see it as if you are confronting them! it's like you are embarrassing them in front of the class. Therefore, they could react with filthy words and embarrass you before the whole class! (Deman, Interview).

Similarly, Alfred said:

> In fact, other teachers discouraged asking questions. It's like you are interrupting them unnecessarily. I remember they used to say 'this is only given; you have to swallow as it is!'

Both vignettes illustrate the teachers' own learning experiences in which questions from students had been circumscribed to maintain order and discipline. Asking questions had meant confronting teachers and thus being disrespectful. Even though the teachers' recounts had been their own experiences rather than how they acted with their own students, it is reasonable to believe that these background experiences might have influenced how they interact with their students. Teachers dominate classroom talk by focusing on delivering prescribed knowledge (see chapter 7). They tacitly seek to control classroom talk and activities, thereby enhancing their authority and students' docility.

The teachers widely believe that lack of prior knowledge and lack of self-responsibility among students constrain attempts to engage them in learning. They believe that lower secondary students can neither take responsibility for their learning nor contribute meaningful ideas during discussions. For the teachers, such students, considering their level, are yet to develop the sense of self-responsibility required to take charge of their own learning. John explained:

> The use of these techniques depends on the level of students. It is very hard to use group discussion and presentation with Form I students. What will they contribute? Maybe I can use it with A-level. At least they have something. They aren't there by mistake.

The phrase 'they are not there by mistake' means a sense of self-responsibility and awareness. Alfred commented:

> Tell me, if you say let me assign them into groups to discuss, do you think Form I will do it? You can even punish them but they don't, I have caned them severally, they didn't! Most of our students these days can't even manage themselves, they have no idea of what they need to do… if you assign them activities, you have to keep barking after them.

Lastly, teachers indicated that students often become suspicious of their mastery of the subject whenever they employ strategies that delegate learning responsibility to students. Often, when teachers choose to assign tasks instead of direct lecturing, students become sceptical of their capability. Nuru explained:

> When you teach by engaging and asking them questions, they begin saying this teacher isn't prepared today, she is idling so that time goes. They may say aaah! This teacher is shallow! She doesn't know this topic.

Such scepticism about teachers' capacity to deliver undermines the teachers' authority as subject experts. Consequently, they seem to have lost faith in interactive pedagogies that optimise students' participation and deeper learning, as Alfred remarked: 'I don't use such [learner-centred] methods because everybody…'. This suggests that the teachers may be sceptical about the relevance of interactive pedagogy considering their context and the type of students.

Overall, students' reticence militates against teachers' attempts to enact interactive pedagogy. Beyond this, deeper cultural and epistemological elements are evident. For example, the type of ideas and contributions that teachers consider to be valid knowledge is the key. Because the teachers view valid knowledge as something codified in textbooks, it is likely that they do not seek students' prior knowledge and thoughts. Closely connected to this is whether teachers present lessons in ways that spark students' interest to contribute. If lessons demand intensive memorisation without promoting personal understanding, students are unlikely to contribute.

Moreover, hierarchical teacher – student relationships in which fears exist around being disobedient, disrupting lessons and making mistakes appear to limit students' engagement. Students seem not to have been socialised into active learning modes; thus, they tend to avoid taking charge of their learning, possibly because they believe that knowledge pre-exists their engagement with it and that their role is to receive it from a teacher. Next, I discuss how contradictory curricula and examinations shape teachers' beliefs.

6.5 Curriculum paradox

Teachers expressed feeling tensions caused by conflicting demands to cover the syllabus content, prepare students for examination and foster deeper learning through activities in (what they considered to be) a limited time. They feel obliged to cover the prescribed content of the syllabus in a specified period. Alfred remarked: 'We are supposed to plan, go to class and teach the content that students are actually required to know (pause), the content per the syllabus'.

Further, school principals hold teachers accountable for students' exam results (See section 6.3.3). Thus, teachers consider that helping students to pass exams is a requirement of their job, as John remarked: 'Here [at Getamock] students have to be given exams… how will they pass if I don't finish the topics'. Under these circumstances, in which teachers are pressured to cover the prescribed syllabus and ensure that students pass their exams, it might be difficult for them to enact approaches that promote deeper learning. Given that examination largely measures students' ability to reproduce textbook knowledge (Vavrus and Bartlett, 2012), it is difficult to see how teachers can prioritise active knowledge construction over the acquisition of factual knowledge.

However, contradictions are evident when the same curriculum policy requires teachers to promote deeper and holistic learning (MoEVT, 2013) while powerful structures such as examination remain largely misaligned with the type of learning envisioned. Teachers are aware that the curriculum requires them to engage students in learning, but they find it difficult splitting instructional time to fulfil these competing demands. Nuru said: 'I know these days they really want us to engage students… but it's difficult you may find you waste a lot of time. Form III-year ends before you finish the topics'.

Often, teachers feel puzzled choosing between focusing on covering the content to prepare students for exams or promoting deeper learning through activities. Because principals reward or sanction teachers for students' examination results, but rarely reward or sanction them for superficial or deeper learning, teachers seem compelled to focus on covering the tested syllabus content and help students to pass exams. John illustrated:

> The issue of assigning activities (pause) I have to judge because they are supposed to cover the content…if I apply that technique (interactive methods) in teaching biology which has many topics, it becomes very difficult because I waste time (pause)… I may lag behind a little bit and others would have finished… they start saying you! You didn't do this. You didn't do that… Maybe teachers who have tried to apply activities have failed we must complete a syllabus on time.

To keep the pace and cover the required syllabus, teachers therefore abandon approaches that promote deeper learning and focus on covering the examined content. They believe students can pass exams without necessarily engaging in inquiry activities. Consistently, they encourage students to learn test-taking tricks and practise with past exam items. Nuru explained: 'Now you are saying that let them look for knowledge [?] why are you bothering yourself? People pass exams by cramming notes and you remain there!'

The impact of curriculum contradiction was evident in the teaching of science practical work aimed at equipping learners with 'inquiry skills'. High-stake exams measure factual knowledge and thus encourage content memorisation. Because the curriculum is overloaded with content, it becomes difficult to focus on both covering content and learning inquiry skills. In this context, teachers narrow practical work to a few topics they anticipate in the upcoming exam. Teachers have devised instinctive skills for guessing with great accuracy the questions that may appear in forthcoming exams. They do this with the aid of advanced instructions they receive from the exam board. Therefore, teachers teach practicals to prepare students for their final examination. John explained when and why teachers teach science practicals:

> It's not teacher's interest per se, it's because they expect those practicals in the exams…they are rarely conducted and they are conducted when there is an examination and students' needs to be prepared for that examination.

Also, Florian illustrated:

> We conduct practicals that we expect in the final examination, may be because we have received advanced instructions[11] or maybe they frequently appear in the examination. For example, according to the current practical examination format, everyone would expect practicals like food test in biology or volumetric analysis in chemistry or light in physics will automatically appear in the final exam… any smart teacher will teach these practicals.

The adverse effects of exams intensify with ability grouping and grade repetition practices. In both schools, teachers cluster students into arts or science streams based on exam scores in science subjects. Deman disclosed: ‘The advantage we chemistry and physics teachers get is that when Form II exam results are released, we screen and group them into arts or science’. Students are grouped into the respective streams after Form II national exam results are released, or they are continually categorised and re-categorised depending on performance in science. At Getamock, failure to attain minimum average score means repeating a grade or dropping out of school. Often, the teachers attributed failure in science to a lack of inborn intelligence to learn. This coincides with teachers’ perceptions of science as a discipline for students with inborn intelligence. Florian illustrated:

> I mean they performed very poorly but they wanted to take science! When we spoke to them, we decided that it is not good to let them fail, just like that. We decided that these students; it will be good to drop them from science. We should take them to other subjects, we thought they should study other subjects rather than struggling with science that certainly they had no ability to learn…. and we talked to students and they themselves consented.

Lastly, teachers’ own beliefs about teaching exacerbate the contradictions imposed by curriculum, exams and time. Teachers often have to reteach content that students have learned on their own through discussions, because for them, teaching must involve knowledge delivery and writing notes for the students. Alex explained:

[11] Advanced instructions are instructions that list the materials, reagents and apparatus that teachers need to prepare for use by students during the practical examination. These are sent to teachers two months before the actual exam.

‘I must give them the correct material even if they discuss and present, so because this consumes a lot of time, you may find that you can’t cover the syllabuses’.

Overall, the pressure to cover syllabus content and prepare students for examination conflicts with teaching approaches that promote deeper learning. In this context, teachers often resort to approaches that they consider effective in preparing students for exams. This is consistent with their espousal of teaching as equipping students with the knowledge they need to pass exams.

6.6 Feasible teaching

The evidence suggests that the teachers might be partly making a deliberate choice of teaching approaches based on their understanding of classroom conditions. This is because teachers seemed aware of learner-centred teaching, as Nuru, for example, remarked: ‘Nowadays, since they introduced this learner-centred teaching, we are supposed to let them [students] participate when teaching’. Further, teachers described teaching that fits both teacher-centred teaching emphasising knowledge delivery and learner-centred teaching that emphasises active student engagement. When asked to describe good science teaching, Alex explained:

> I can say two things; the way science is supposed to be taught and the way we teach science or ideally when you advise someone on how science should be taught and the way we practice teaching science.

Then, he went on to explain teaching from the two perspectives:

> Ideally, a science teacher should assign students group activities. Doing more practicals and allow them to ask questions in class. But at the moment our teaching is mainly transmissive, it means students depend only on the teacher and notes the teacher provides.

This indicates that teachers do partly understand how they should be teaching, although their understanding is limited because they exclude students’ prior knowledge. What other factors, then, could be influencing their decisions?

Teachers at Marera acknowledged their transmissive teaching practices and consider these to be the most feasible approach in their school context, which is characterised by a shortage of resources and large class sizes. Such contextual constraints justified transmissive teaching. Alex suggested, ‘In reality, we can’t engage students, the class is very big and students have no books, only the teachers have books’. Nuru remarked, ‘For example, there are other practicals like photosynthesis; we conduct those very rarely because the equipments are not readily available’. Deman expounded:

> For example, if I want to engage students in testing how solid changes directly to gas (pause) I mean sublimation but the reagents like iodine are not there, what can I do? It is difficult… In our school, we just do practicals occasionally, that’s it.

At Getamock, classroom conditions were better but teachers complained of being demotivated to improve their teaching because of low pay. John explained:

> Science teachers aren’t committed, when they think of the system [mmh!]. It could be either the principal is not paying our benefits or the school owner doesn’t care about our welfare or… sometimes we teachers we go out during the examination invigilation and marking, so maybe some of us are not given those chances for a long time. There are also seminars that they pay for attendance. The impact of that now! Everything may be there but nobody is interested.

This suggests that teachers may not teach as expected even where classroom conditions are better. It seems that teachers’ commitment to teaching is key, as Alfred exemplified: ‘Teachers will not do practicals [?] absolutely they won’t because they need commitment. If they aren’t committed, maybe if they themselves are interested in doing practicals’. Indeed, teachers understand that some of the supplies they need for inquiry activities are locally available. Nuru disclosed: ‘It is true … other practicals are not costly, we could just use what is available in our local context. Like demonstrating a structure of flower, you could just take a hibiscus flower and bring it to the classroom’. These accounts paint a picture of interrelated multiple factors interacting in complex ways to justify and produce models of teaching that teachers believe best fits their school contexts.

6.7 Chapter summary

In this chapter, I have identified six key factors that might have shaped and formed science teachers' beliefs in the context of secondary education in Tanzania. First, teachers' beliefs are consistent with their own childhood, schooling, and training experiences. For example, when growing up, teachers experienced fear-inducing childrearing practices that inculcated in them feelings of fear, obedience, and submissiveness. The teachers espouse and employ the same practices to maintain discipline and enhance their authority over students in their schools. Further, teachers' beliefs accord with administrative structures, expected norms and students' classroom behaviours. For example, teachers' espousal of teaching and learning as covering syllabus content and ensuring students pass their exams appears to correspond with bureaucratic demands for covering the mandated syllabus and preparing students for their exams. What the teachers espouse as good science teaching and learning may or may not reflect their own actual practices; I turn to this in the next chapter.

Chapter 7: Science Teachers' Practices

7.0 Introduction

In this chapter, I present analysis of science teachers' classroom practices. When analysing teaching, I focused on specific elements, including lesson structure, task, activities, and teacher–student interactions. My intention was to understand how teachers' beliefs manifest in these crucial elements. In the next section, I describe ideas about the classroom and its constituent elements, before examining lesson structure in more detail.

7.1 The classroom

7.1.1 Structure

Both schools in this study share the same notion of an ideal classroom. This comprises blocks of three to five rectangular rooms, each with a wooden door. At Getamock, all classrooms have steel and glass windows. At Marera, some classrooms have no windows, while others have windows with wooden frames and steel bars. Generally, classrooms are smaller at Getamock than at Marera, although those at Marera are overcrowded. Evidently, Marera draws large numbers of students from nearby suburbs to offer them affordable secondary education. Its classrooms have concrete floors and painted walls. Unlike at Getamock, classrooms at Marera show obvious signs of deterioration, implying lack of regular maintenance.

In both schools, classrooms have a chalkboard, student tables and chairs, and a teacher table that is often like the student tables. No classroom has a teacher chair, implying that the teaching role fundamentally does not involve the teacher sitting. Further, there are no classroom displays, which may be indicative of a teaching style that mainly involves talking and listening rather than interacting with visual materials.

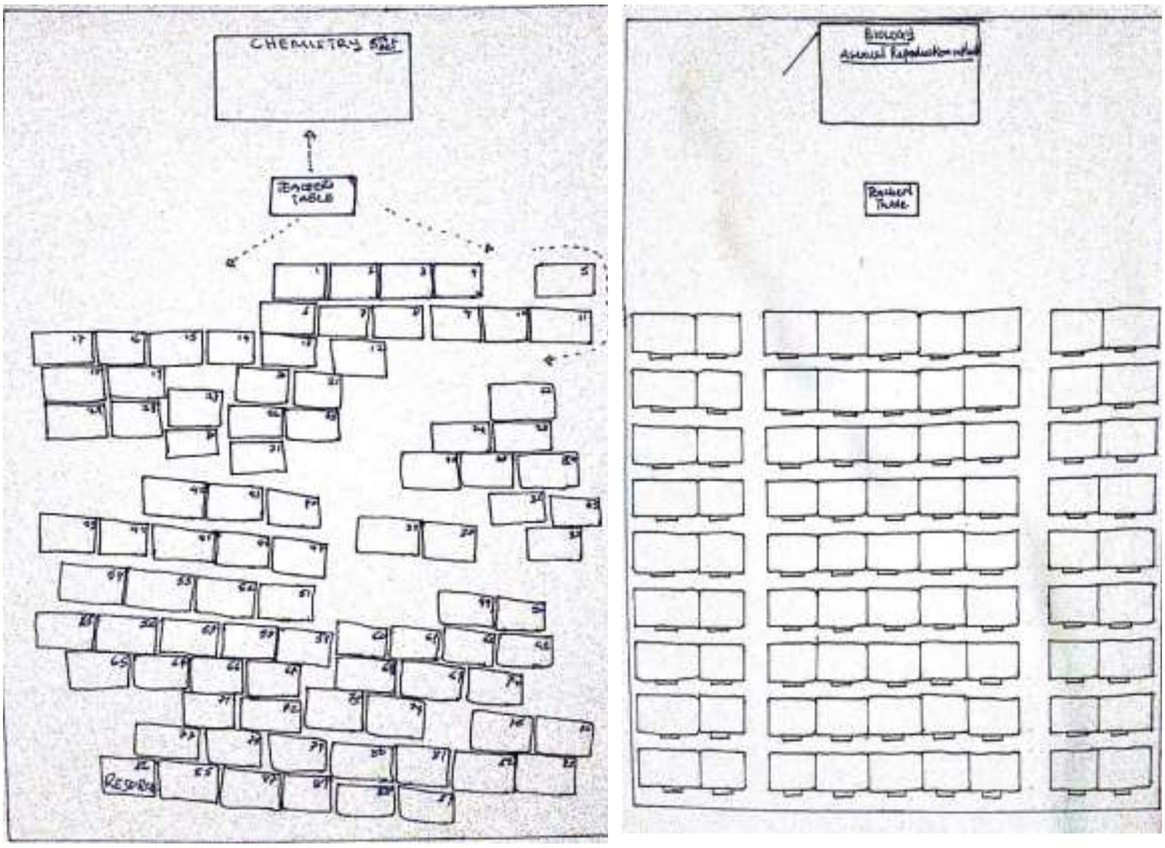
Except for the laboratories, the chalkboard is the only teaching resource used often. Each school has three science laboratories, each equipped with essential requirements such as electricity, water, and gas taps. Laboratory reagents, apparatus and instruments are stored in cupboards. In both schools, the laboratory rooms are similar sizes, ideally designed to accommodate up to 40 students at a time. The structure of the classroom tells only part of the story about the teaching activity taking place inside it. How the classroom is organised illuminate further.

7.1.2 Organisation

In both schools, students sit on metal chairs and wooden-topped, metal-legged tables. These are arranged in a traditional classroom setup with rows of chairs and tables facing the chalkboard and the teacher. At Marera, students typically sit in rows, one behind the other, interacting with the teacher or the chalkboard but rarely with each other (figure 7.1a, b). Ideally, students sit in clearly ordered rows, but as shown in figure 7.1a, students in one Chemistry lesson bunched up their chairs and tables. When I asked Deman, who gave this lesson, about this seating arrangement, she said:

> Often, when you see them sitting like that, no teacher has been attending lessons since morning. They decided to clump up so that they can easily chat. I didn't want to ask them to sit in a proper way. I didn't want to disturb you waiting them to sit as they are supposed. However, that's because there were no teachers attending since morning otherwise [?].

Therefore, figure 7.1b shows the most typical seating arrangement at Marera, whereas figure 7.1a shows an arrangement that is less typical at Marera.



a b

Figure 7.1: Typical seating arrangements at Marera

At Getamock, student tables are wide (figure 7.2), which allows two to three students to share a table. Tables are arranged in rows and columns such that each group of three students sits behind each other, all facing the chalkboard and the teacher. This arrangement could allow student–student interactions among those sharing the same table; however, the arrangement was organised for reasons other than optimising instructional effectiveness. Florian, the deputy principal for Getamock, disclosed:

> Like five years ago, we had them use single tables like that one (pointing to a table in the corner of his office), but most of them got broken, so we decided to purchase those ones. They were cheaper compared to the other ones.

Indeed, the opportunity for active interaction among students sharing the same table remained untapped because teachers rarely assigned activities to table members.

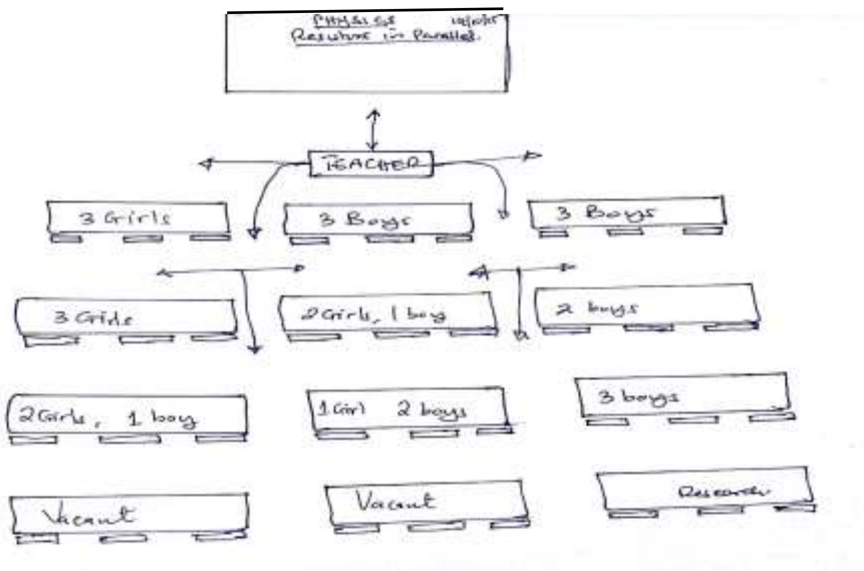
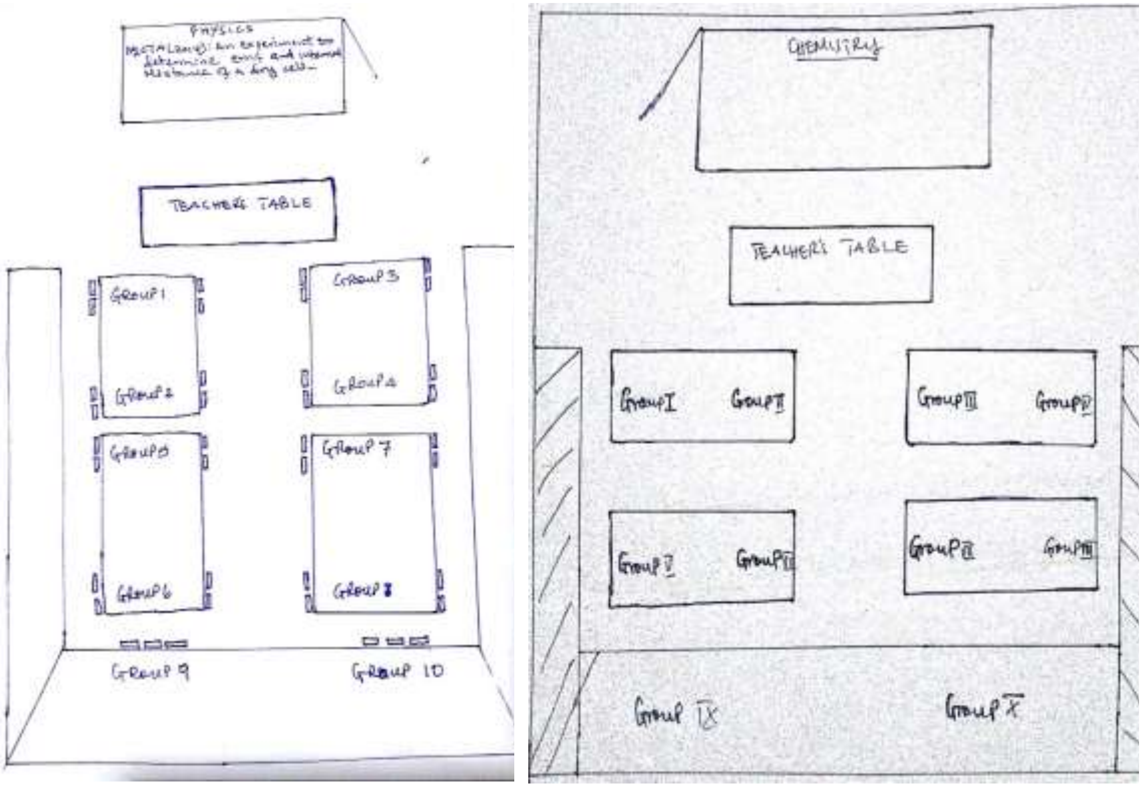


Figure 7.2: Typical seating arrangement at Getamock

Typically, laboratory setups share similar features in both schools (figure 7.3a, b). Up to 80 students use the laboratories at Marera at any one time depending on the class size, making the room overcrowded during practical lessons. Often, students conduct practical work in ten groups of up to eight students each. Groups are distributed along the middle and side benches. Each side bench has gas and water taps (not shown in the figure).

I did not observe practical lessons at Getamock, because teachers were waiting for the ‘advance practical examination instructions’ from the National Examination Council (NECTA). Teachers disclosed that they rarely teach practical work except when preparing students for final exams, often after receiving advanced instructions. Indeed, the four practical lessons I observed at Marera were for final-year students. These excluded four teacher demonstrations in which teachers showed real objects. Teachers in both schools draw on their experiences of marking national exams to predict the topics that could appear in upcoming practical examination.



a Marera **b Getamock**

Figure 7.3: Typical laboratory setups

7.1.3 Space and resource use

In the foregoing sections, I identified desks, chairs and laboratory benches as spaces in the classroom and laboratory where teaching and learning takes place. In addition to these, teachers and students use textbooks, teacher notes, student exercise books, chalkboard, and miscellaneous laboratory supplies. In what follows, I describe the way teachers and students use spaces and resources.

First, teachers rarely altered the default classroom organisation of students seated in rows and columns with a unidirectional focus on teacher and chalkboard. Thus, during the teaching and learning process, students mostly remained seated one behind the other, concentrating their attention on the teacher, who normally stood at the front. Teachers often spoke from the front of the class, and occasionally moved between rows to check seat work. In one post-observation interview, Nuru disclosed her beliefs behind this classroom setup:

> It becomes easy to know what everyone is doing. You saw, I just caught that boy who… He didn't write notes for the previous lesson and he wasn't writing today. I gave him up to the end of the break time, I want all the notes written.

This suggests that the teachers consider a traditional seating arrangement to be convenient for controlling and managing students. Indeed, the teachers used verbal and physical means of controlling students' behaviours, including pointing fingers, keeping eye contact and verbally reprimanding students to pay attention.

Teachers largely interacted with the whole class, and rarely with individual students (see section 7.2.5). Even at Getamock, where three students shared each table, student–student interaction was minimal during the lessons. The only exception was when teachers called students to the front to share a solution with the rest of the class. When asked questions, students raised hands, stood where they were and answered questions, often addressing the teacher rather than the class. When called to the front to work at the chalkboard, students either talked in low voices or did not talk at all. It was difficult to follow their thinking. The vignette below illustrates this:

> Florian called group 1 presenter to front. She walked to the front holding a paper with answers to the questions they attempted on her hand. She took a chalk and turned to the chalkboard to write the definition of 'bond' while Florian stood aside. While facing the chalkboard, and looking shy, she read in low voice 'we said bond is anything that (stammered) that hold two or more things together' (Albert, Field notes).

Often, after a student had finished writing a solution on the chalkboard, the teacher had to explain everything to enable others to follow the thinking. Teachers often know the answers because students reproduce them from textbooks. Occasionally, teachers teach theory lessons in the science laboratories. Even though the laboratory setup permits clustered seating (see figure 7.3), the conventional seating arrangement in which students sit in rows all facing the teacher and chalkboard was maintained.

Further, the chalkboard was the main teaching resource used for writing lesson notes and demonstrating answers for students to copy. Teachers used textbooks to prepare lesson notes and assign students end-of-chapter questions or past exam items as homework. Students mainly relied on the lesson notes they copied during the lesson, which appears to suffice the primary purpose of passing exams. Teachers organised and delivered notes in a way that students could easily memorise and recall during exam, which clearly illustrate the widespread culture of learning to pass exams. Teachers reinforced exam culture through classroom questioning, in which they asked questions that prompted recitation of lesson notes.

Students’ use of textbooks during lessons was observed very rarely at Marera and only occasionally at Getamock because access to textbooks was restricted. At Marera, there is no designated library; thus, teachers keep textbooks in the storeroom managed by the head of academic affairs. Ideally, students should be able to borrow textbooks from the storeroom, though this is practically difficult because the manging teacher is often unavailable due to teaching responsibilities. Alex disclosed:

> It is difficult for them to access books, because the teacher who is responsible for that room (pointed to storeroom) is often unavailable. That’s one, but our students [?] will they read even if they are given books? They don’t.

Although Getamock has a library, there is no serving librarian. One language teacher manages the library from the library room. Access to the library is restricted to when this teacher is available. Generally, restricted access to wide sources of knowledge means that learning is focused on memorising teachers’ notes. In the following, I turn to specific elements of the actual lessons.

7.2 The lesson: Structure, tasks, activities, and interactions

In this section, I analyse the events that take place from the moment a teacher enters the classroom. Specifically, I describe the overall structure of the lesson, before moving on to selected elements of the lessons, including tasks, activities, and interactions. The aim of this is to understand how teachers' beliefs about science knowledge, teaching and learning are implicated in these elements of the lesson.

7.2.1 Lesson structure

Teachers precisely divided lessons into 40-minute single periods, 80-minute double periods and three-hour laboratory practical sessions. All the lessons I observed followed regular periods, and the lesson activities took place within the precisely allotted time. A loud bell rang between lessons to signal teachers of the culmination of one lesson and commencement of the next. In most instances, the teacher for the next lesson would be at the door within minutes after the bell waiting for the current teacher to verbally conclude the lesson. When planning lessons, teachers had to organise everything to fit within the specified lesson duration because there was no time to pursue anything beyond the allotted time.

This rigid framing of the lesson has its foundation in government circulars, syllabi, and school timetables. These official documents clearly dictate lesson length and structure. For example, in the Biology syllabus, the Chief Education Officer powerfully wrote to teachers:

> Column seven constitutes the suggested number of periods per each sub-topic. The number of periods has […] taken into consideration the length of the sub-topic to be taught. *Teachers are advised to strictly adhere to the framework of the allocated time so that teaching does not lag behind. Lost instructional time should always be compensated without fail* (MoEVT, 2013, p. viii, emphasis added).

Consequently, school timetables clearly stipulate the number and duration of each lesson to reflect curriculum policy prescriptions. Therefore, when planning lessons, teachers are compelled to divide topics into short episodes of learning tasks for students to carry out in the specified time. Interestingly, the teachers I observed seemed to have an intuitive grasp of time such that they taught lessons within the schedules without lagging.

All the lessons I observed had specific goals. These had clearly structured and predictable introduction, presentation, and culmination phases. A typical introduction phase, which lasted 10 minutes, comprised several events, including greetings, dividing the chalkboard into equal portions and writing the topics covered during the lesson. Students also pulled out their notebooks and wrote the topic (see box 7.1).

Box 7.1: Part of lesson introduction phase (Alfred, Form III Physics)

(1) *Students:* Stood up and greeted 'good morning teachers'

(2) *Teacher:* Good morning.

(3) *Researcher:* Walked to the back of the room where there were plenty of vacant seats. This was because some students had just left the class, as they were not taking Physics as among the subject options they were studying[4].

(4) *Teacher:* Wrote subject physics, date and topic, then…

(5) *Students*: Pulled out their notebooks and began writing

(6) *Teacher:* Turned to students, and asked, 'where did we ended last time?'

(7) *Students*: Silent.

A review of the previous lesson or assignment followed, most often through a question-and-answer strategy. There was usually a moment of silence between the teacher asking a question and the students raising their hands to respond. During this moment, students quickly revised through their lesson notes to recall and locate the answers the teacher sought. Occasionally, some students could recall answers directly without revising, possibly because they had memorised them. Such students often volunteered their response immediately.

Most students, however, scanned through their notebooks to recall answers. While the students were revising, the teacher kept repeating the question to cover up the moment of silence and allow students to locate answers. Repeating questions helped the students to keep track of the question as they searched for the answers in their notebooks (see turns 21–24, box 7.2). When students raised their hands, teachers selected any of them to respond (see turns 24–35, box 7.2).

Box 7.2: Question-and-answer episode (Nuru, Form IV Biology)

(21) Teacher: Also, we learned forms of asexual reproduction, what are they? Eeeh! What are they? Who can tell us, (*Looked around for any volunteer, there was none*).

(22) Students: Silent, perused through notes.

(23) Teacher: What are the types of asexual reproduction?

(24) Student: A boy raise hand (*After scanning through his notes*).

(25) Teacher: Yes, John.

(26) Student: Stood and answered[2] 'Fragmentation'

(27) Teacher: Good, another one?

(28) Student: Raise hands[3]

(29) Teacher: Yes, Mariam.

(30) Student: Answered 'Budding'.

(31) Teacher: That's right, next!

(32) Student: Three of them raising hands.

(33) Teacher: Mmmh! Paschal.

(34) Student: Answered 'vegetative propagation'.

(35) Teacher: Good! Another one.

Teachers judged students' answers and gave affirmative comments such as 'correct', 'that's right' and 'good' when the answer was correct (turns 27, 31 and 35, box 7.2). For incorrect responses, the teacher either outright said 'no', shook the head, raised the eyebrows, and used similar facial expressions to indicate rejection of answers. Teachers invited other student volunteers to attempt answering, often without pointing out why the answers had been rejected (see turns 94–102, box 7.3). At a deeper level, rejecting students' answers suggests that teachers command uncontested authority to arbitrate and dismiss answers they consider 'incorrect' without seeking students' justification to support their rejected answers. Students often responded individually or chanted. Teachers named a topic they would cover during the lesson to mark the end of the introduction phase. The vignette in box 7.3 illustrates this.

Box 7.3: Concluding the introduction phase (Nuru, Form IV Biology)

(39) Teacher: Correct! Let's now proceed. We have already done spore formation, now we are proceeding with 'budding'. We are proceeding with what?

(40) Students: Chanted 'Budding'

(41) Teacher: Yes! In budding, a new organism is produced from an outgrowth called bud. An outgrowth called what class?

(42) Students: Chanted 'Bud'

[Omitted]

(93) Teacher: She complained 'Aah! We did this in form three don't you remember?', then she pointed to one student 'you tell us!'

(94) Student: Stood up, 'stem'

(95) Teacher: No! Another one!

(100) Student: Stood up and answered 'pollens'

(101) Teacher: No! Pointed to another student saying 'you!'

(102) Student: Stood up and responded 'Ovum [?] Ovule'

(103) Teacher: Organ! Organ! Organ! (*She emphasised after realizing that students couldn't differentiate between organ and cells*).

Some teachers such as Deman and Florian began a new topic by stating the lesson objectives, while other teachers moved on to presentation, and a few, such as Alfred, began by writing lesson notes on the chalkboard. See turn 85, box 7.4.

Box 7.4: Stating objectives for new lesson (Deman, Form III Chemistry)

(84) Student: Silent. None volunteered.

(85) Teacher: That is about last period. Today we are going to talk about 'chemical properties of metal Hydroxides' and our objectives for this lesson are; turned to the chalkboard and wrote:

i. Action of heat on metal hydroxide
ii. Action of mineral acids on metal hydroxides
iii. Uses of metal hydroxides

(86) Students: Wrote objectives in their notebooks.

(87) Teacher: Starting with number one. (Wrote objective on a chalkboard) Then, she asked 'do all hydroxides decompose when heated or not?'

(88) Students: Silent.

As indicated in turn 85 of Deman’s lesson (box 7.4), teachers covered a series of topics in an episodic format (Alexander, 2001). The presentation phase in Deman’s lesson, for example, covered three subtopics in one lesson. Each episode may or may not relate to the rest and had a beginning and a recap. This episodic structure of lessons may be a means of adapting to externally imposed timeframes. Because time is not negotiable, episodic lessons make it possible to conclude the lesson at any time. Overall, presentation was the longest of all the three phases.

Presentation phase largely involved the teacher talking and delivering textbook knowledge. Teachers explained facts, concepts and illustrated procedures and formulas. They interspersed their verbal presentation with questions and answers (turns 93–95, box 7.5). They wrote lesson notes on the chalkboard for students to copy (turns 95–97, box 7.5). Occasionally, teachers demonstrated concepts and solved calculations for students. In addition, they called students to the front to demonstrate a procedure or a solution (turns 158–161, box 7.5). However, overall, seated work involving listening, watching the teacher and writing notes dominated this phase.

Box 7.5: Lesson presentation phase (Deman, Form III Chemistry)

(93) Teacher: Good, wrote the hydroxides of potassium (KOH) and Sodium (NaOH) on the board. The she continued 'actually the hydroxides of these two metals do not decompose when heated. The rest do decompose when heated to give metal oxides and....?'.

(94) Students: Silent.

(95) Teacher: With raised voice 'to give metal oxides and what?'

(96) Students: In unison 'and water'.

(95) Teacher: Yes! To give metal oxides and water. Sodium and potassium are very reactive metals, when their hydroxides are heated, they do not decompose easily. The hydroxide of less reactive metals such as Magnesium decompose to form metal oxides and water when heated (*Wrote notes as she talked*).

(96) Students: Copied notes on their notebooks.

(97) Teacher: After writing, she turned to students and asked 'yes do you understand when I say the rest? Can you mention others metals which are below in the electrochemical series?' Eeeh! Pointed to a student.

(158) Teacher: The colour of iron II hydroxide is green, when you see unknown compound with green colour, it is iron hydroxide though you are going to test to confirm. She then wrote the equation Fe(OH)2 + HCl → and asked; who can come and complete this reaction? (*Then she turned to students who were raising hands*) 'eeeeh .... (*name a student*) come and complete the reaction'.

(159) Student: Stood up and walked to the chalkboard, wrote $Fe\ (OH)_2 + 2HCl \rightarrow FeCl_2 + 2H_2O$.

(160) Teacher: Good, as I said iron hydroxide could be green or light green. It can be totally green or light?

(161) Students: recited; 'green'.

The lesson conclusion phases varied. Some teachers highlighted concepts and ideas that students needed to explore further before the next lesson, while others invited students' questions. Yet others simply summarised the lesson to signify its culmination. However, the teachers concluded most lessons by asking questions that reviewed the content covered during the presentation phase. The vignette (box 7.6) from a Form I Chemistry lesson by Deman illustrates this.

Box 7.6: Lesson conclusion phase (Deman, Form I Chemistry)

(160) Teacher: So today, we looked at the meaning of air. Meaning of what?

(161) Students: Recited 'air'.

(162) Teacher: What is air?

(163) Students: Silent (*although the definition was still on the chalkboard*)

(164) Teacher: Repeated 'what's air Form one?' (*with emphasis*).

(165) Students: Some raised hands.

(166) Teacher: Yes, you!

(167) Student1: Stood up and answered 'air is the colourless [stammered] od… test less mixture of gases'.

(168) Teacher: Good. Air is a colourless, odourless, and test less mixture of different what? (*Cued for whole class chant*)

(169) Students: Chanted 'Gases'

(170) Teacher: We also saw mmmh! [pause] composition of air! What are the components of air?

(171) Students: Many raised hands.

(172) Teacher: Yes, You!

(173) Student 2: Stood up and answered 'gases'.

(174) Teacher: Good and we said what gases form the air?

(175) Students: Silent.

(176) Teacher: What gases can we find in air? (*With demanding voice*).

(177) Students: Two raised hands.

(178) Teacher: (*Complained*) Only two? Only two? Eeh you!

(179) Student 3: Stood and answered 'nitrogen'.

(180) Teacher: Good. We have nitrogen which constitute 78% of all the gases in the air. What else? You (*now, many more were raising hands*).

(181) Student: Oxygen.

(182) Teacher: Correct! Oxygen which makes 21% of the what? (*Cued for whole class choral response*).

(183) Students: Chanted 'Air'.

(184) Teacher: Another gas? (*The bell rang to signal the end of the 80 minutes' period*).

(185) Students: Silent.

(186) Teacher: I can hear the bell is ranging. Okay for today we are going to end there. When we meet again we are going to see the next part. Okay?

(187) Students: Chanted 'yes'. And we went out of the class.

Lesson conclusion phases involving a question-and-answer strategy were the longest of all. In lessons where the teacher asked few questions during presentation phase, lesson conclusion involving question-and answer was the longest. When teachers concluded lessons with question-and-answer episodes, these were primarily aimed at supporting students to commit content knowledge to memory.

John explained: ‘I want to see if they remember what we have been going through. When I ask them questions, I can clearly know those who were following’.

When they asked questions in this phase, teachers focused on key ideas and concepts that may be examined in upcoming examinations. Either they signalled possible topics that could be the focus of exams or they asked questions that mimicked examination items. See box 7.7 for an illustration of this.

Box 7.7: Comparing teacher questions[12] and exam items

Teacher questions

1) Teacher: … Let us make short revision about compounds and elements… who can define the meaning of compound? <u>What is compound?</u>

2) Students: … (silent)

3) Teacher: (repeated) ‘<u>What is compound?</u> eeeeh! Yosef’.

4) Student: … (answered) ‘is a substance which consist of two or more elements chemically combined together’

5) Teacher: Good! … Another one! <u>What is element? Who can define what is element?</u>

6) Student: (hands up) … (bidding to answer)

7) Teacher: eeh Maria!

8) Student:…‘is the combination of two or more elements chemically combined together’ (defined compound, but teacher did not notice).

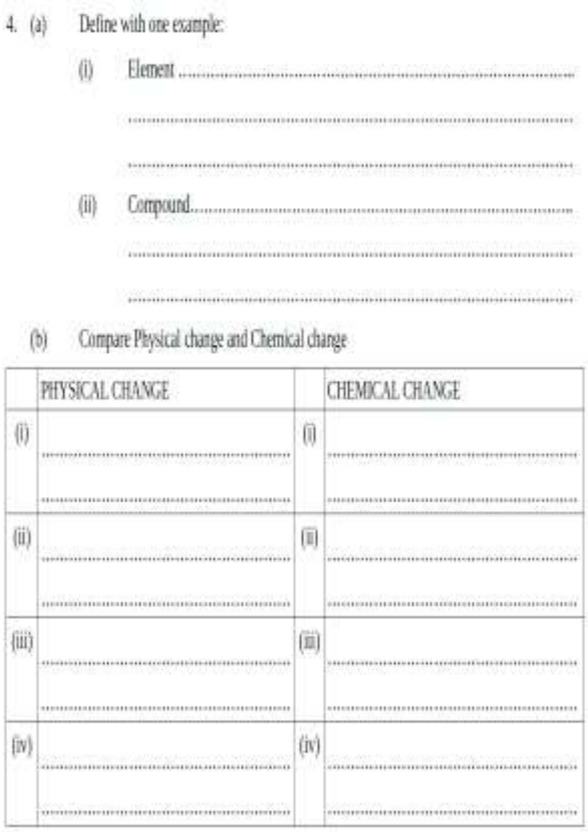
***9) Teacher*:** … <u>what is the difference between chemical change and physical change?</u>

…

***10) Student*:** In chemical change, energy is used while in physical change… (continued).

(Florian, Form I Chemistry, field notes)

Exam questions


4. (a) Define with one example:

(i) Element ....

(ii) Compound ....

(b) Compare Physical change and Chemical change

PHYSICAL CHANGE	CHEMICAL CHANGE
(i)	(i)
(ii)	(ii)
(iii)	(iii)
(iv)	(iv)

Extract from Form II Chemistry, National examination (2006).

[12] Teacher questions are underlined.

1) Teacher: Good... What is first aid?

2) Student: … Is a first help to an injured person.

3) Teacher: No! No… Another one, you!

4) Student: … 'Is the first help to an injured person before taking him or her to the hospital'

5) Teacher: That's correct, sit. What is a first aid kit?

6) Student 18: … Is a small box where first aid equipment are kept (reading from a notebook).

7) Teacher: Good! … Okay. What are the components of first aid kit? You eeeh!

***8) Student*:** A soap.

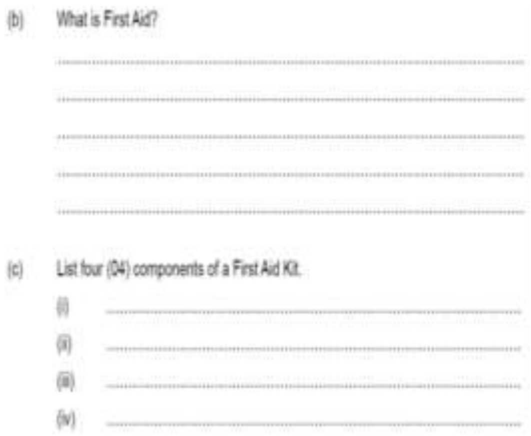
9) Teacher: A soap is used for?

10) Teacher: Yes 'for cleaning wounds'. What else?

11) Student: a pair of scissors.

12) Teacher: Good! For what? (continued….)

(John, Form I Biology, field notes)



(b) What is First Aid?

(c) List four (04) components of a First Aid Kit.

(i)

(ii)

(iii)

(iv)

Extract from Form II Biology, National examination (2005).

The structure of practical lessons

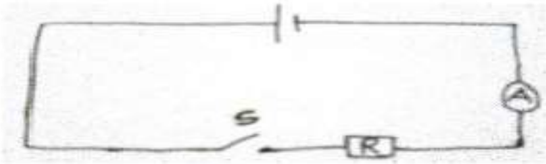
Out of the 30 lessons, I observed only 4 practical lessons in Form IV class that was preparing for the final national exam. Since I began collecting data in August 2015, when Form IV students were preparing for the national examination that took place in November 2015, I considered the practical lessons I observed to be extraordinary rather than the norm. Further, because I did not observe practical lessons in other classes, it is reasonable to believe that the lessons I observed in Form IV were primarily to prepare them for exams. Indeed, the teachers disclosed that they often conduct practical lessons after receiving 'advance instructions' for practical exams from the national examination board. This means that they teach practical lessons in preparation for the final examination.

Typical practical lessons had a slightly different structure from theory lessons. Initially, before the practical session began, the teacher wrote past practical exam question(s) on the chalkboard and prepared the necessary reagents and apparatus. Box 7.8 shows my observations during a Physics practical lesson taught by Alex.

Box 7.8: Sample practical question (Alex, Form IV Physics)

I erased the chalkboard while Alex entered his office, which was a small room inside the physics laboratory. He came out with a past exam paper and began writing a question on the chalkboard. It was a practical exam question of the past year. Students also copied a question on their notebooks. The question was as follows:

An experiment to determine the E.M.F and internal resistance of the cell. You are provided with a Cell, Switch, Ammeter and Resistance box. Connect the set as shown below and attempt the questions that follow:



i. Use a resistance R=2 ohms in the resistance box, close the switch "S" and record the reading of the current "I" indicated by Ammeter(A).
ii. Repeat the procedure in (i) above for the value of R =4, 6, 8 and 10
iii. Tabulate your observations as follows:

R(Ohms)	I(A)	1/I(A^{-1})
2		
4		
6		
8		
10		

a. Plot the graph of R against 1/I
b. Determine the slope of the graph
c. If the graph obeys the equation R=E/I-r then:
   i. Suggest how E and R may be evaluated.
   ii. From your graph, compute E and r.
   iii. State one source of error and suggest one way of minimizing it.
   iv. Suggest the aim of this experiment.

As indicated in box 7.8, the teachers draw practical lesson tasks from past national examination papers, the aim being to encourage students to practise exam-type items as Alex disclose:

> These questions are often repeated every year; they might repeat it this year also, I want them [students] to be familiar on how these kinds of questions are done. They need to remember this; they may come across it in the examination… past exam questions are like the actual ones, it's important that they practice and get experience of doing paper two [meaning practical exams].

This confirms that the teachers have developed intuitive skills to deduce the questions that may be repeated in the national exams, because of their experiences of marking national exams. Nuru explained:

> In Biology, we are familiar with the common specimen they ask in the exams. We usually prepare these things in advance and students practise how to answer different questions basing on the organism (Post-observation interview).

Practical sessions commenced by assigning students into groups of up to eight, as shown in box 7.9.

Box 7.9: Assigning students into groups (Deman, Form IV Chemistry)

extended conversation until 3.00 pm when students began entering chemistry laboratory. When all students entered, Deman took a piece of paper and read out names of students to form groups. She continued as follows:

(1) Teacher: When you hear your name, you will be in the group that will sit there (pointing to the first point). Then she read: 1.......2............3..........4.........5.........6.....7......8......

(2) Students: Initially they were talking but when addressed; they paid attention, those whose names were read moved to the first point. They were six girls and two boys.

Afterward, the teacher delineated stepwise instructions that the students needed to follow to arrive at the expected results, as illustrated in box 7.10.

Box 7.10: Stating experiment procedures (Alex, Form IV Physics)

(1) Teacher: When doing experiment, you should adhere to these procedures (pointed to the procedures on the chalkboard). The he read the procedures as written on the chalkboard: 'first, you take a wire and you connect to what?'

(2) Students: In unison 'Ammeter'.

(3) Teacher: Joined the chant; 'to the ammeter, [...] then you connect Ammeter to Resistance box. Resistance what?

(4) Students: Recited 'Resistant Box'.

(5) Teacher: Then you take another wire, you connect it to resistance box and you touch it with a terminal of wire connected to battery and you record ___? (*Cued question*).

(6) Students: Chanted 'Current'

(7) Teacher: You record the current reading on the Ammeter while the resistance is 2 ohms. Then you repeat the same procedure for 4, 6, 8 and 10 what?

(8) Students: Chanted 'Ohms'

(9) Teacher: Okay, start the experiment and tabulate your results as shown on the question.

The middle of the practical lesson had two parts. One comprised student-led activities, which involved setting up the experiment and collecting data. While students experimented, and collected data, the teacher moved between the student groups, checked progress and provided necessary assistance.

The second part was a teacher-led discussion, in which the teacher worked with students to answer questions associated with the experiment. Answering these questions often required students to use the data they had collected. Teachers often mimicked the exam style of answering questions, some instances of which are portrayed in box 7.11.

Box 7.11: Mimicking exam style of answers (Alex, Form IV Physics)

(43) Teacher: There is a graph and graph paper. You just laugh; you will see what will happen in the exam. It will depend on how they (those who will be marking national examination) will decide that day, whether those who write titles out of the graph but on the margins of the graph paper will get marks or not. Look here! He took a graph paper. 'This is a graph and these are the margins of a graph paper. Your tittle should appear on the first line of a graph and not on the margins of a graph paper, are we together?'

(45) Teacher: Title is one mark, if you do the way you think, not the way you're told by the teacher, it means you lose one mark; Is that clear?

(65) Teacher: Right! If you divide this by 9, (wrote 8/9) you will end up with approximately 1. Now our horizontal scale is 1cm represents 1 amperes. If you do this correctly, you have your marks. Do you understand?

(73) Teacher: So, I am telling you all these are marks. If you draw lines correctly its one mark, if you show all the points correctly one mark. I know these things I have been marking exams for many past years. Sometimes I feel sorry because people lose marks for small things like drawing correct lines. The bell rang to signify end of three-hour practical session and he concluded the lesson as follows:

When the teacher demonstrated a solution, students listened and copied this down as an exemplary solution. The conclusion phases of the practical lessons often involved a brief closing statement prompted by the school bell.

7.2.2 Lesson task

Teachers could portray a lesson task in a statement of learning objectives in their lesson plans. However, I focused on the actual learning intention that a teacher strived to achieve when teaching, instead of the 'learning intents' stated in the lesson plan. Based on my experiences of teaching and supervising student teachers, I was aware that teachers associated checking their lesson plans with teaching inspections conducted by the inspectorate department. Therefore, it could be unproductive to ask teachers to provide their lesson plans for analysis because they could have associated this study with a teaching inspection. Moreover, the teachers often prepared lesson plans by copying the syllabus to align their lesson plans with it. School inspectors expected a standard lesson plan to be coherent with the syllabus, as Alfred disclosed: 'They come to inspect the syllabus; they want to see if you're planning your lessons and if you're teaching according to the syllabus. They look at the content; are you teaching according to the syllabus?'

Because I foresaw these discrepancies, I decided to analyse the tasks that teachers facilitated when teaching. Some teachers explicitly stated the lesson objectives at the start of the presentation phase, while others did not. However, it was possible to discern the learning task that the teachers tried to foster, by analysing the 'presentation segments' of their lessons. I analysed and classified lesson tasks based on the procedures I explained in section 4.3.4. In what follows, I describe the general features of the tasks, before moving on to present emerging clusters of tasks.

General features of the tasks

Generally, each lesson presentation phase comprised a series of episodic tasks. This meant that learning with one task was possible without necessarily referring to other tasks. In short, teachers precisely framed and tightly bounded tasks in terms of content and time, to allow teaching one task independently without making the lesson meaningless.

Some tasks were linked, making it impossible to learn one meaningfully without another. A typical example was a Form I Chemistry lesson by Deman, in which students learned the ‘meaning of air’, ‘composition of air’ and ‘uses of air’. In this case, it was not possible to learn meaningfully about composition and uses of air without learning the meaning of air. However, linked tasks were relatively rare compared with self-contained episodic tasks. Only 4 of the 18 analysed lessons contained linked tasks.

Another notable feature was ritualised learning involving recitation and repetition of content knowledge. A typical teaching episode started with the teacher defining a core concept in a task, followed by description of the process and examples. For example, in a Form II Chemistry lesson, Florian defined ‘chemical bonding’ first, then described the formation of a chemical bond and gave examples of covalent, polar covalent and ionic bonding.

Teachers then turned to students with closed questions requiring them to recite the content presented. This was often on the chalkboard; thus, students could simply read and recite. Often, students overtly resisted talking by not volunteering to respond to the teacher’s questions (see turns 164–173, box 7.12). In this case, teachers often recited or repeated the content themselves, in the hope that the material would eventually become stuck in students’ minds. Deman explained why she repeated content:

> I think they have not been able to pick it up. Therefore, when I find they don’t want to answer questions, I just repeat what I told them. Let them hear for another time, may be to some it will get into their minds.

It could be that students see their role as receiving knowledge from the teacher; thus, their reluctance to talk could be a means of ensuring that teachers stick to a knowledge delivery role.

Box 7.12: Students' reluctance to answer questions (Deman, Form III Chemistry)

(162) Teacher: After the reaction if you leave the mixture for short time, it may change colour, it may become reddish brown. Repeated 'Reddish ______?' (*Cued for students to chant the omitted word*).

(163) Student: Chanted 'brown'.

(164) Teacher: Why does it change to reddish brown?

(165) Students: Silent.

(166) Teacher: Repeated the question 'why does it change to reddish brown?'

(167) Students: Still silent.

(168) Teacher: When it changes to reddish brown it is because iron 2 has changed to iron 3. (*Wrote the equation on the chalkboard*) $Fe^{2+} \rightarrow Fe^{3+}$ does it loses or gain electron?

(169) Students: Mostly silent but one boy who whispered 'it gains'

(170) Teacher: Yes! He said it gains; what about others?

(171) Student: Another boy shouted 'it loses'

(172) Teacher: We learned in form two about oxidation, oxidation means___? (*Cued question*).

(173) Students: Silent.

(174) Teacher: It means it loses_____?

(175) Students: Chanted 'electrons?'

A third notable feature was that tasks required students to receive, accept and reproduce the knowledge exactly the way the teacher presented it. This is evident in the type of questions teachers asked between their verbal presentation. The vignette in box 7.13 is typical of this approach.

Box 7.13: Teachers' questions (John, Form II Biology)

(25) Teacher: ... So water and minerals are transported from one place to another....This means in plant, water and minerals are transported from the soil to the roots and from the roots to other parts of the plant body through what?

(26) Students: Chanted 'Xylem'.

(27) Teacher: Therefore, we say xylem is involved in the transportation of water and mineral salts. All these are obtained from the...? (*Cued intonation demanding whole class chant).*

(28) Students: Chanted 'soil'.

(29) Teacher: Joined the chant; 'yes soil'. Okay, and so xylem is the one that is involved in transporting water and other mineral salts. And other mineral elements.

[Omitted segment]

(36) Teacher: Eeeh! (*Continued writing while talking*) Phloem: This is used for transportation of food from the site of photosynthesis to the other parts of the plant body. (*Stopped writing and explained*), therefore xylem themselves are used to transport what?

(37) Students: (*few chanted*) water and nutrient elements.

(38) Teacher: Water and mineral elements while phloem transport food. And where is food found? Where is the food manufactured?

(39) Students: Silent.

(40) Teacher: In the leaves because photosynthesis takes place in the green parts of the plant which in this case is the leaf. Therefore, food is made in the leaves and is transported to all other parts of the plant body by phloem. Okay, is that right?

(41) Students: Chanted 'yes'.

(42) Teacher: So, you need to know that xylem transport water and minerals while phloem transport food. Do you understand?

(43) Students: Chanted 'Yes'.

(44) Teacher: And where does the food come from?

(45) Students: Silent.

(46) Teacher: From the leaves where photosynthesis occurs. And where do mineral salts come from?

(47) Students: Chanted 'soil'.

(48) Teacher: From the soil. So, this means that water and minerals from the soil move up but food materials come from the leaves and move down. Okay?

(49) Students: Chanted 'yes'... [Lesson continued].

The excerpt in box 7.13 illustrates how John interspersed his verbal presentation with factual questions that prompted students to recite the content he presented. In turns 25–27, for example, John culminated his description of the role of xylem in transporting water and mineral elements by asking closed factual questions that prompted students to recite factual answers 'xylem' and 'soil'. John repeated the same question in turn 46, eliciting students to recite the same answer in turn 47. The question in turn 36 also sought to prompt students to recite the description that had been given earlier in turns 25–27. A similar exchange is noticeable in turns 38–44. The question in turn 38 then elicited students to recite the content John had just presented in turn 36. As a result of students' reluctance (turn 39), John had to restate his explanation, mimicking the type of answers he was seeking from students (turns 40 and 42). John repeated in turn 44 the same question that he had asked in turn 38. As in turn 39, students remained silent, compelling John to recite the same explanation for a second time. This exchange substantiates how students' reticence to interaction militates against teachers' attempts to engage in recital learning.

Overall, learning tasks required students to receive, memorise and reproduce as faithfully as possible the content knowledge delivered by the teacher. Even when a task demanded higher cognitive engagement, teachers either lowered the level of cognitive engagement to recall or were compelled to do so when students resisted answering questions that required elaborate responses. Further, when students resisted, teachers often recited the material themselves, underlining key words and phrases to be memorised. Most importantly, teachers rarely sought to elicit students' ideas beyond the recall of the content they delivered. In addition, it was not common to find teachers rephrasing, probing, or asking students to explain and justify their responses. Next, I present categories of tasks.

Categories of tasks

I present in table 7.1 the results of task analysis that examined the type of knowledge and the level of cognitive demand in the 18 selected lessons. I generated data by tallying the tasks in each lesson to the task's knowledge and cognitive demand categories. Since counting and classifying tasks into categories is not a clear-cut process, it might be useful to consider the data in table 7.1 as more indicative of relative emphasis than fixed categories. Even with this margin of error, the insights generated illuminate the practices of science teachers in this study.

Table 7.1: Task demand in 18 science lessons

Knowledge dimension	Cognitive process dimension						Total
	1.Remember	2.Understand	3.Apply	4.Analyse	5.Evaluate	6.Create	
A. Factual	137	44	6	0	0	0	**187**
B. Conceptual	30	37	0	2	0	0	**69**
C. Procedural	7	4	14	1	0	0	**26**
D. Metacognitive	0	0	0	0	0	0	**0**
Total	**174**	**85**	**20**	**3**	**0**	**0**	**282**

The type of knowledge promoted

Looking at the type of knowledge the tasks promote, it is clear that teachers predominantly promoted the acquisition of factual knowledge. Over 66% of learning tasks sought to promote factual knowledge, compared with 24.4% of tasks that promoted conceptual knowledge, and 9.2% of tasks that promoted procedural knowledge. Teachers often restricted their teaching to delivering factual knowledge even when the task potentially required a certain level of conceptual understanding. A typical example of this practice can be seen in box 7.14, turn 85 onward.

Box 7.14: Sample task (Deman, Form III Chemistry)

(85) Teacher: That is about last period. Today we are going to talk about 'chemical properties of metal Hydroxides' and our objectives for this lesson are; turned to the chalkboard and wrote:

i. Action of heat on metal hydroxide
ii. Action of mineral acids on metal hydroxides
iii. Uses of metal hydroxides

(86) Students: Wrote objectives in their notebooks.

(87) Teacher: Starting with number one. (Wrote objective on a chalkboard) Then, she asked 'do all hydroxides decompose when heated or not?'

(88) Students: Silent.

(89) Teacher: Hydroxide of metal higher in the electrochemical series do not decompose when heated. What metals are higher in the electrochemical series? You tell me (*pointed to a student*).

(90) Student: Stood and answered 'Potassium'

(91) Teacher: Good, next, you!

(92) Student: Sodium

(93) Teacher: Good, wrote the hydroxides of potassium (KOH) and Sodium (NaOH) on the board. The she continued 'actually the hydroxides of these two metals do not decompose when heated. The rest do decompose when heated to give metal oxides and….?'.

Tasks (i) and (ii) in box 7.14 could best have begun with a hands-on experiment using hydroxides of metals located in different levels of the electrochemical series. Students could have carried out thermal decomposition of hydroxides of different metals and compared the thermal stabilities of reactive metals such as sodium and potassium to less reactive metals such as copper and lead. If Deman had done this, the factual question (turn 87) and the subsequent verbal description would have been unnecessary. Instead, this could have been an opportunity to reflect on and discuss experiment results. Since the school has a Chemistry laboratory equipped with basic supplies for the teachers' needs, I could not attribute the approach Deman took to material constraints.

None of the tasks sought to encourage students to reflect on their own thinking or justify why they thought the way they did, thus I could not classify any task into a metacognitive category. Indeed, the teachers rarely pursued students' ideas, thoughts and interests beyond testing whether they had acquired the textbook knowledge.

The cognitive demand

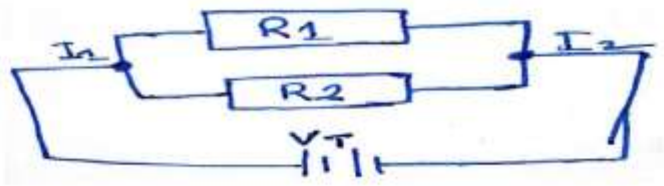
The results in table 7.1 suggest that most tasks required students to recall factual and conceptual knowledge. Over 61% of the tasks were limited to the cognitive process of remembering. Occasionally teachers, however, focused on helping students make sense of the knowledge they delivered. Around 30% of the tasks appeared to promote students' understanding. Teachers employed various strategies to help students make sense of the knowledge. Some notable strategies included linking tasks to the content covered in the previous lessons, using familiar examples and using illustrations when presenting, as shown in turns 46 and 47 in box 7.15. In this case, Alfred linked his description of 'parallel connection' of resistors with 'series connection', which he had covered in the earlier lesson.

Box 7.15: Using illustrations (Alfred, Form II Physics)

(44) Teacher: Okay! Now let us look at parallel connection of resistors. Wrote parallel connection of resistors on the chalkboard. He then took his exercise book and began writing notes on the chalkboard while students copied.

(45) Students: Took their notebooks and wrote the notes.

(46) Teacher: He wrote 'in a parallel connection all resistors share a common input point (node) and a common output point (node). He sketched this as follows:



(47) Teacher: 'Stop writing and pay attention', then he started explaining 'when resistors are in series, current passes one resistor after another that is resistor 1 receives current and passes it to resistor 2, then to resistor 3'. Then he drew an illustration:

He continued explaining 'what is important here is that the output of one resistor becomes input of another resistor and the like. Now this is different from the parallel connection. Are we together?'

(48) Students: Chanted 'yes'.

A relatively small proportion of tasks (7%) required students to apply knowledge. Tasks requiring students to apply knowledge were mostly found in Physics (18 tasks), rarely in Chemistry (2 tasks) and none in Biology. In Physics, for example, these types of tasks required students to apply a formula or use a procedure to solve physics problems, as shown in turns 81–83 in box 7.16.

Box 7.16: Tasks requiring students to apply a formula (Alfred, Form II Physics)

(81) Teacher: Now let's do this example… wrote an example on the chalkboard *'for example; calculate the effective resistance of two resistors 3Ω and 7Ω when connected in parallel'.* Then he wrote and started solving saying 'here you must prepare data first;

Data give R1 = 3Ω
R2 = 7Ω
R_T= ?

Now from our formula…$1/R_T = 1/R_1+1/R_2$. If we substitute R_1 and R_2 then it becomes?

(82) Students: Silent, writing.

(83) Teacher: Wrote 1/RT = 1/3 + 1/7 =0.4761. Therefore, R-total is 0.476. Then he turned to students to see how they are doing. Have you finished?

(84) Students 1: Replied 'yes' handing over his work to teacher.

Only 1% of the tasks were analytic. In Chemistry, a typical analysis task required students to distinguish metals from non-metals based on their physical and chemical properties (Form I Chemistry lesson, Florian). Even when the task is analytic, it was not clear whether students were deeply engaged or they simply recalled the answers. For example, the distinctive properties of metals and non-metals that students listed may reflect their recall of textbook content rather than critical analysis of metallic and non-metallic elements. No task required that students create a solution or original products. This may be because the teachers were concerned with conveying textbook knowledge. In what follows, I describe the activities students performed to carry out the task.

7.2.3 Learning activity

I analysed lessons to identify the type of activities in which students participated. I adopted the definition of a learning activity as a means through which students accomplish a task (Alexander, 2001). Alexander views both tasks and activities as indispensable aspects of the learning experience. For example, if the learning 'task' requires students to determine electromotive force (e.m.f.) and the internal resistance of a dry cell (as in Alfred's Physics lesson), the learning 'activity' may entail measuring the current passing through different resistors using the same dry cell. This task also involves observing, manipulating measuring instruments, drawing graphs and calculating unknown variables. In short, the task forms the 'intended conceptual growth', while an activity is a technical aspect of the learning process (Alexander, 2001).

When analysing activities, I focused on identifying the types of activities, how these were organised and the overall purpose. I confined analysis to the 18 lessons initially considered for task analysis. Practical lessons involved solving past exam items that were designed with predetermined activities. Teachers rarely altered these items because their intention was for students to practise exam items in preparation for the national examination. Deman substantiated this when we conversed after one of the practical lessons: 'They [students] need to be familiar with these kinds of questions…no surprises when they find the same in the final exams'. In what follows, I describe how I counted activities.

Counting activities

I read transcripts of the selected lessons and identified nine featured activities, including listening, answering questions, writing notes, observing, reading, drawing, asking questions, discussions and plenary presentations. Next, I critically examined each of the 18 lessons to count and tally the frequency of each activity. I tallied when one activity replaced another. For example, I counted two 'listening' and one 'observation' when a listening episode was interspersed with an observation. A typical example is shown in turns 135–140 in box 7.17, in which Nuru asked if there was any student who did not know 'ginger', and the students remained silent. Next, she showed a piece of ginger for students to see. Lastly, she asked a question, and the students affirmed in choral unison. In this case, I counted one 'silence', one 'observation' and one 'answering question' activity.

Box 7.17: Counting activities (Nuru, Form IV Biology)

(135) *Teacher*: Yes, you!

(136) Student: Tangawizi.

(137) *Teacher*: Good, Tangawizi. Is there anybody who doesn't know Tangawizi? [Pause]

(138) *Students*: Silent.

(139) *Teacher*: Here it is (*Took out a piece of Ginger from a small bag*). Do you see, this swollen stem, this is its one that grows below the soil? It acts as a food storage. Clear?

(140) *Students*: In unison 'yes'.

Table 7.2 shows the activities and their respective frequencies of occurrence.

Table 7.2: Activities in the 18 science lessons

Activity	Frequency of occurrence	Percentage	Average
Listening/looking	947	45.53%	53
Answering questions	746	35.87%	41
Writing	194	9.33%	11
Reading	87	4.18%	5
Asking questions	30	1.44%	2
Observing	22	1.06%	1
Drawing	17	0.82%	1
Clapping hands	9	0.43%	1
Demonstrating/showing	8	0.38%	0
Calculating	8	0.38%	0
Talking to teacher	4	0.19%	0
Discussing in groups	1	0.10%	0
Presenting plenary	1	0.10%	0
Total	**2080**	**100.00%**	

The results in table 7.2 indicate that listening to teachers' verbal instructions, answering teachers' questions by reading responses from lessons notes and writing lesson notes were the most frequent activities. Other learning activities, from asking questions to presenting in plenary, were occasional. I closely examined each of the most featured activities.

The most prevalent activity was ‘listening’ to teachers when they verbally presented subject knowledge. When presenting, teachers stood at the front of the class and delivered the lesson by explaining and highlighting key concepts (turn 91, box 7.18). In addition, they wrote notes for students to copy. In his Form II Physics lesson, for example, Alfred twice repeated his presentation on the ‘equation for resistors in parallel’. After this, he selected a student to repeat the explanation. Similar patterns of repeating explanations were common in the Form I Chemistry lesson given by Florian. An excerpt from his lesson illustrates this:

> Yeah! Is the representation of the compound… is the presentation… is the representation that uses symbols to show the proportion of elements found in that compound. [Repeated] ... Is the representation of the what? (continued before students could respond) ...of the compound by the use of symbols… by the use of chemical symbols of the elements present in a certain compound. For example, we say water is a compound, are you there.

Between their verbal presentations, teachers asked closed questions, which required affirmative or single-word responses from students. Practices involving teacher talk intermixed with questions and answers were widespread in all the lessons I observed (see turns 89–90, box 7.18).

Students remained seated and listened. They followed the teacher talk and noted the key words and phrases repeated for them to memorise (turn 86, box 7.18). Students also answered questions asked by the teachers when lecturing. They either gave choral whole-class answers or stood up and answered individually. Thus, answering teacher questions was the most frequent activity after listening to teacher talk. Box 7.18 illustrates some of these practices.

Box 7.18: Lesson segment illustrating activities (Nuru, Form IV Biology)

(85) *Teacher*: (*Began explaining while writing*). 'This is a type where part of the plant develops into a new plant without association with the reproductive organs. In this method, a new plant is produced from parts of the parent plant such as roots, stems and leaves. Some of the plants that can be reproduced in this way include apples, tea and cassava'. (*Stopped explaining but continued writing*).

(86) *Student*: Listened while writing everything in their lesson notebooks.

(87) *Teacher*: Re-reads notes she wrote on the chalkboard 'so we say in this type of reproduction a new plant is formed from the parent plant without involving what?'

(88) *Students*: Silent

(89) *Teacher*: Without involving reproductive organs. Without involving what?

(90) *Students*: Chanted 'reproductive organs'

(91) *Teacher*: Joined the chant 'without association with the reproductive organs' (*she underlined key words such as 'reproductive organs', 'without association', 'parent plant)*. Then she asked 'what are the reproductive organs in plants?'

(92) *Students*: Silent. None of them volunteered to respond.

(93) *Teacher*: She complained 'Aah! We did this in form three don't you remember?', then she pointed to one student 'you tell us!'

There were two forms of writing. Writing lesson notes that teachers wrote on the chalkboard was the most prevalent and accounted for over 80% of writing activities. Copying lesson notes was a solitary activity that students did while seated at their desks. Students also participated in writing when teachers called them to the front of the class to share a answers, as illustrated in turns 35 and 43 in box 7.19.

Box 7.19: Students writing at the front of the class (Florian, Form I Chemistry)

(30)*Teacher*: Very good. Another one! We looked at first 20 elements. So before proceeding who can write a chemical symbol for Aluminium?

(31)*Students*: No reply.

(32)*Teacher*: Repeated, 'who can write a chemical symbol for Aluminium?'

(33)*Students*: Some raised hands.

(34)*Teacher*: eeeh you!

(35)*Student*: Stood up, moved to the front, picked a chalk and wrote 'A' as symbol for Aluminium and returned to her seat (looked nervous).

(36)*Teacher*: Intervened before a student reached her seat and asked 'is she correct?'

(37)*Students*: Chanted 'Nooo!'

(38)*Teacher*: Good try another one!

[Omitted]

(42)*Teacher*: Come forward and write the symbol for Aluminium (*gave her a chalk*).

(43)*Students*: walked to the chalkboard, wrote AL as a symbol for Aluminium, and gave back a chalk.

(44)*Teachers*: Asked 'Is she correct?'(*Cued for whole class choral response*).

(45)*Students*: Chanted 'Yes'

For example, in turns 35 and 43 in box 7.19, Florian called students to the front of the class to write chemical symbols for elements. I observed similar practices in a Form III lesson by Deman, in which she invited students to the front to write balanced chemical equations showing thermal decomposition of metal hydroxide.

Another notable activity was reading which involved scanning or staring at lesson notes to recall answers when asked questions. Of the 87 instances of reading, 85 involved explicit scanning through the lesson notes. I observed the remaining two incidents in a Chemistry lesson where Florian assigned tasks that required students to read books. In this lesson, Florian distributed books and instructed the students to read, extract and present ideas from them.

Teachers occasionally invited students to ask questions. In some lessons, teachers successfully prompted students to ask questions, while in other lessons, students resisted asking questions (see box 7.20).

Box 7.20: Prompting students to ask questions (Deman, Form III Chemistry)

(180) Teacher: In addition to that, they form salt and water. The same apply to nitric acid, which forms nitrates and water; something to notice is that all nitrates are soluble in water. We are going to deal with the issue of solubility in the coming practical, so we are going to have soluble nitrates. Is there any question so far?

(181) Students: Silent.

(182) Teacher: Where you don't understand?

(183) Students: Silent.

(184) Teacher: Now if you don't have questions, let's proceed with the uses of metal hydroxides

Deman unsuccessfully attempted to prompt students to ask questions (turns 180 and 182, box 7.20). When students asked questions, they mainly sought information from teachers or other students. Responses often entailed a teacher reiterating a segment of explanation or procedure.

I recorded 22 incidents of 'observations' that involved students observing a teacher or a student demonstrating a solution or showing real objects to exemplify concepts. The extract in box 7.21 illustrates this.

Box 7.21: Observing teacher/student demonstration (Nuru, Form IV Biology)

(143) Teacher: Do you see this? (*Took out a bulb from a bag*).

(144) Students: Chanted 'Yes!'

(145) Teacher: This is an onion. Okay! Now show me; where are the scale leaves? (*Walked between rows*), you show me (*touched a boy on shoulders*), go and cut an onion and then show us scale leaves.

In this lesson, Nuru showed real objects, such as onions, grasses, and ginger, to exemplify parts of plants involved in asexual reproduction. Other activities, such as drawing diagrams and illustrations, and clapping hands to motivate students who gave correct answers, were occasional. I observed calculating activities only in Physics lessons by Alex and Alfred.

Lastly, I observed group discussions and plenary presentations in a Chemistry lesson taught by Florian. Florian first asked students to sit in groups, then assigned one question to each group, and gave them a book to read, discuss and write down answers that they then presented in plenary. Questions assigned included: 1) define bonding; 2) what is chemical bonding?; 3) explain why atoms bond; 4) describe the formation of ions; 5) what is electrovalent bond?; and 6) list the properties of electrovalent compounds.

Although this activity could have been an opportunity for active participation, the way this was organised limited students' participation to mere copying of answers that textbooks provided directly. A quick glance at some textbooks used by students during discussions revealed that the answers were obvious[13]. Therefore, the activity

[13] Although I had snapshots of the textbook pages, I could not secure copyright permission, and thus I cannot present them here.

simply involved copying the required answers from textbooks and presenting them before the class. In short, students' cognitive engagement was limited to identifying answers relevant to questions from the textbooks, instead of thinking and generating ideas from their own experiences. Most importantly, Florian did not organise similar activities in subsequent lessons. This means that this practice was temporary rather than a routine.

7.2.4 Nature of teacher questions

Teachers' questioning practices may reflect their beliefs about subject matter, teaching and learning. Tables 7.3, 7.4 and 7.5 respectively show the types of questions asked, the purposes for asking and the types of feedback given by teachers to students' answers.

Types of teacher questions

The results in table 7.3 show that teachers mostly asked closed factual questions on the content of previously taught topics. Questions requiring single-word answers, simple affirmative responses and predetermined textbook-based lists of items were widespread compared with other types of questions.

Table 7.3: Types of teacher questions

Main categories	Sub-categories	Average no. of questions/ lesson	Total no. of question in 18 lessons	% of each category
Managerial		3.8	69	7
Closed	Affirmative	12.9	232	24
	Word	18.8	338	35
	List	9.4	169	17
	Define	3.0	54	6
	Procedure/event	1.7	30	3
Open	Probing	3.4	62	6
	Divergent	1.2	21	2
Total		**54.2**	**975**	**100**

In total, closed (affirmative, word, list, define and procedure) questions accounted for 85% of all questions asked. These questions mainly required single or predetermined multiple answers. Conversely, thought-provoking questions that required students to express their thoughts, views and experiences were uncommon. For example, on average, fewer than four questions probed students' divergent thoughts.

Even when teachers asked open thought-provoking questions, students' 'habits and behaviours' appeared to constrain them from engaging in critical thinking and conveying divergent viewpoints. Students in the classrooms I observed were accustomed to reciting textbook facts rather than their own viewpoints. Further, teachers often rejected plausible answers that students gave when such answers did not reflect textbook knowledge (see box 7.22). This overemphasis on textbook answers indicates that the teachers place greater confidence on the superiority of textbook-based scientific ideas.

Box 7.22: Rejecting answers not aligned with textbooks (Florian, Form I Chemistry)

(87) Teacher: [...] what can we use to extinguish class B fire?

(88)Students: Silent.

(89)Teacher: Class B fire, [...] like fire caused by kerosene at home ....

(90)Students: Some raised hands.

(91)Teacher: eeh you! Tell us

(92)Student1: [...] cover with soil

(93)Teacher: Cover with soil! No, another one?

... [Omitted]...

(97)Student4: [...] Water

(98)Teacher: No! [...] Class B! Class B! He repeated eeh! You

(99)Student5: Tree leaves, you cut a ... (*Interrupted*)

(100)Teacher: Did I say that? Another one! You [...]

(101)Student6: [...] carbon dioxide.

(102)Teacher: Good... Another one

(103)Student7: Cover with a container or buc... (*Interrupted*)

(104)Teacher: Is that correct?

(105)Students: Chanted 'no'

(106)Teacher: Another one, you

(107)Student8: Foam or dry powder.

(108)Teacher: Good [continued]

Consequently, even though questions in the 'open questions' category could potentially prompt divergent ideas, the answers that teachers sought from students and those they themselves gave were largely textbook-based. In box 7.22, for example, the question 'what can we use to extinguish class B fire?' elicited divergent responses (turn 87). Answers such as 'covering fire with soil or container' (turn 92), 'using water' (turn 97) and 'fresh tree leaves' (turn 99) could be reflective of students' knowledge of how fire is 'locally' extinguished, while the use of 'foam and carbon dioxide' are textbook-based. In this case, Florian rejected answers based on students' first-hand experiences and instead sought textbook answers (turn 100). Although Florian acknowledged that the methods of firefighting that students listed could be used at home, he still considered them to be incorrect because 'class B fire is caused by liquid fuel such as kerosene which floats on top water and continue burning'. Therefore, it is likely that Florian considered the students' ideas to be inferior over the textbook knowledge. Next, I discuss the purpose of classroom questioning.

Purpose of classroom questioning

The results in table 7.4 show that teachers mainly asked questions to 'elicit' affirmative, single-word or predetermined lists of responses. In addition, they asked questions to 'check' whether students could recall the content of previous lessons. Questions intended to 'elicit' when combined with those intended to 'check' accounted for over 90% of all questions in the 18 lessons I analysed.

Conversely, questions aimed at probing students' thinking, seeking clarifications and scaffolding by focusing students' thinking were scarce. However, one should exercise caution when interpreting the frequencies presented in table 7.4. This is because the reasons underlying teachers' questions were tacit rather than obvious, making the categorisation less clear-cut, although the insights do shed light on the relative emphasis of teachers' questions.

Table 7.4: Purposes of asking questions

Type of question	**Purpose of asking question**						**Total**
	Elicit	Check	Probe	Inform	Clarify	Focus	
Managerial	52	14	0	3	0	0	**69**
Affirmative	116	114	0	2	0	0	**232**
Closed word	196	127	7	0	8	0	**338**
Closed list	129	34	6	0	0	0	**169**
Closed define	21	27	0	4	0	2	**54**
Closed procedure	25	3	2	0	0	0	**30**
Open probing	13	6	42	0	1	0	**62**
Open divergent	5	0	16	0	0	0	**21**
Total	**557**	**325**	**73**	**9**	**9**	**2**	**975**

How students answered questions, and types of responses sought

Out of 975 questions asked, 746 were answered by students either individually (43%) or in a whole-class chant (57%). In addition, teachers directly answered 51 questions when students showed reluctance to speak. Lastly, teachers asked 178 questions, but when students remained silent, the teachers ignored such questions and continued with the lesson.

Considering the type of questions teachers asked (table 7.3), most questions required recall of short single words or lists of concepts while few needed extended responses. When answering questions, students often scanned quickly through their notebooks to locate answers or stared consistently into their notebooks, as illustrated in box 7.23.

Box 7.23: Excerpt from Form IV Biology by Nuru

(14) Student: Stood and answered: 'is a type of reproduction… (*Stared on her notebook*) in which new individuals are reproduced from a single parent… (*Stared again*) without the formation of gametes'. (*Stammered and repeatedly gazed her notebook*).

These habits were prevalent for questions that needed extended responses that took longer to memorise and recall. Some teachers discouraged students from reading back their lesson notes to answer the questions (turn 170, box 7.24).

Box 7.24: Excerpt from Form IV Biology by Nuru

(169) Student: 'Is a type whereby part of the plant develops into…' (*A teacher interrupted after realising a student was reading from a notebook word to word*).

(170) Teacher: No close that notebook and repeat.

(171) Student: Is the… (Stammered, could not proceed, and could not repeat her answer).

(172) Teacher: Another one?

Others did not notice this behaviour, but some overtly encouraged students to refer to their notebooks to recall and reproduce their answers. The comment by Deman in box 7.25 illustrates this.

Box 7.25: Encouraging students to answer questions by reproducing notes

(25) *Teacher*: Only two! Don't you have your notes with you there? (*Explicitly encouraged students refer to notes for answers*).

Students often hesitated answering questions that demanded thinking, working out an answer, organising and presenting it in a meaningful way. They remained silent even when the teacher explicitly prompted them to respond. These habits were prevalent in questions requiring whole-class chanting and in questions specifically targeted to individual students. I noted 193 incidents of whole-class silence in response to teacher questions, and 36 incidents of individual student silent response. These totalled 229 instances during which students stayed silent despite explicit attempts to prompt them to speak. The extract from a Form I Physics lesson taught by Alex in box 7.26 illustrates students' reluctance to answer questions.

Box 7.26: Students' reluctance to answer questions (Alex, Form I Physics)

(12) *Teacher:* Joined the chant 'fluid', then he walked to his table and picked his lesson notebook, scanned through several pages, then he turned to the chalk board and began writing again. He wrote, 'Archimedes' principle states that…, then he stopped writing and turned to students and asked, 'who could try to state Archimedes' principle?'

(13) *Students:* No reply

(14) *Teacher:* Repeated, 'who can try to state Archimedes principle?'

(15) *Students:* No reply

(16) *Teacher:* Who? Can you try? (*Pointed to a student*).

(17) *Student 1:* No reply.

(18) *Teacher:* After realizing no one was volunteering, he pointed to a boy 'yes' [name].

(19) *Student 2:* Stood and answered 'Archimedes principle states that (He *was reading initial sentence from the chalkboard, then he attempted to stare at his notebook, but he couldn't as the teacher kept looking at him… he kept silent*).

(20) *Teacher:* After realizing that the boy could not answer without reading from a notebook, he instructed, 'okay sit down'.

(21) *Student 2:* Sat.

(22) *Teacher:* Continued writing 'Archimedes principle state that… (*Stared on his notes*) when the body is totally or partially immersed in a fluid… [Paused] it experiences an up-thrust that is equal to the weight of the fluid dis…? (Cued)

Between turns 12 and 17 in box 7.26, Alex prompted students to state Archimedes' principle beginning with a whole-class and specific individuals, but they remained silent.

In turn 18, Alex asked a boy, identified in the excerpt as student 2. Alex recognised this boy to be among the bright students in the class because he often directed questions to him when no one else could answer. Even this boy had to read an answer from his notebook. When the teacher maintained eye contact with him, he became stuck and could not continue. It seemed that Alex discouraged students from reproducing answers from lesson notes. When we conversed after the lesson, I asked Alex about his view of students' silence:

> That is their nature; those are the students we have… most of them shy away answering even if they knew the answers. Maybe they feel embarrassed to speak before others or they feel like others will see them stupid if the answer is wrong (Post-observation interview).

Often, when attempts to prompt students to answer questions were unsuccessful, the teachers answered the questions themselves by repeating their verbal presentation (see turn 22, box 7.26). Teachers also resorted to asking simple affirmative or recitation questions when students resisted questions demanding extended answers. Typical examples of this type of teacher–student interactions is Deman's lesson shown in box 7.12, in which she recapped her description of the reaction between the hydroxide of iron ($Fe (OH)_2$) and hydrochloric acid (HCl) with the phrase 'it may become reddish____'. This prompted students to recite the omitted word 'brown'. However, when Deman asked an open question prompting students to 'explain why the mixture of iron hydroxide and mineral acid changes to reddish brown', students remained silent. This was so even after she repeated a question severally. This compelled her to answer the questions herself, thereby keeping a knowledge-giving role. This suggests that teachers and students overtly and covertly contribute to the tenacity of transmissive teaching in schools.

Teachers' feedback

Teachers overtly used phrases that embodied the type of feedback they gave when students answered questions. Table 7.5 shows the categories of feedback given by the teachers.

Table 7.5: Types of teachers' feedback

Type of questions	**Type of feedback**						**Total**
	Affirm	No feedback	Praise	Provide answer	Reject	Collective judgement	
Managerial	7	59	3	0	0	0	**69**
Affirmative	97	124	0	1	4	6	**232**
Closed word	206	74	25	19	4	10	**338**
Closed list	68	18	53	11	15	4	**169**
Closed define	16	7	17	4	10	0	**54**
Closed procedure	5	4	11	10	0	0	**30**
Open probing	23	15	16	4	1	3	**62**
Open divergent	4	3	2	12	0	0	**21**
Total	**426**	**304**	**127**	**61**	**34**	**23**	**975**

The results in table 7.5 show that the teachers gave affirmative feedback using words such as 'correct', okay' and 'exactly' to approve students' answers. They gave this type of feedback for over 40% of the questions they asked students. I included in this category instances in which teachers repeated students' answers, to indicate their approval without using affirmative words.

Further, teachers gave no feedback for 30% of questions they asked students. This was prevalent for managerial, affirmative, and closed single-word questions. In turns 59–62 in box 7.27, for example, Nuru asked an affirmative question (turn 59), but she gave no feedback (turn 61) following a whole-class choral response (turn 60).

Box 7.27: Excerpt from Form IV Biology by Nuru

(59) *Teacher*: So, that is fragmentation, right?

(60) *Students*: Chanted 'Yes'.

(61) *Teacher*: Can anybody tell us how fragmentation occurs? (*Question apparently intended to find out is students were attentive, but they remained silent yet the explanation was still on the chalkboard, also on their notebooks as they have just finished writing*). Started explaining herself. 'In fragmentation an organism naturally breaks into several parts. Each part then develops into new complete organism'. Examples of organisms that reproduce in this way include flatworms, Echinoderms and Sea Anemones.... Is that clear?

(62) *Students*: Chanted 'Yes'

(63) *Teacher*: Any question?

In many instances, teachers' questions constituted 'expressions' with omitted words uttered in intonations that cued whole-class choral responses. Such expressions were often the repetition of teachers' foregoing sentences, as in turn 77 in box 7.28, where students recited 'propagation', which was part of the teacher's phrase 'the fifth type is vegetative propagation'.

Box 7.28: Excerpt from Form IV Biology by Nuru

(75) *Teacher*: That's correct. So, that is the 4th type of asexual...? (*Cued for a whole class chant*).

(76) *Students*: Chanted 'reproduction'.

(77) *Teacher*: The fifth type is vegetative propagation. Vegetative what?

(78) *Students*: In unison 'Propagation'.

Teachers also praised students for correctly answering questions. They used exclamatory words such as 'good', 'very good' and 'brilliant' to applaud correct responses. Overall, 'affirmative feedback', 'teacher praise' and 'no feedback' constituted 87% of feedback given by teachers to students' responses. For the rest of the questions, teachers either answered the questions themselves, rejected answers or sought a collective class verdict.

One remarkable feature of teachers' feedback is that teachers answered over half (12 out 21) of the open questions themselves (see table 7.5). This confirmed students' reluctance to answer open cognitively demanding questions. Further, teachers rejected students' answers for some questions and prompted further attempts by other students (see, for example, turn 14, box 7.29).

Box 7.29: Rejecting answers (John, Form I Biology)

(7)*Teacher:* [...] what is a first aid for burns?
(8)*Students:* Silent (*perused notes*)
(9)*Teacher*: eeh who can tell us? You.
10) Student1: Press affected area gently with block of ice.
... [Omitted]...
(13)*Teacher*: Good, another one?
(14)*Student3*: Apply fresh bee honey on the affected area.
(15)*Teacher*: No. What else did I say?
(16)*Students3*: Apply moist pack soaked in a backing soda.
(17)*Teacher*: Good ... (*continued*)...

Scenarios of questions in which teachers sought a collective decision by prompting whole-class choral responses can be seen in turns 36 and 44 in box 7.19, in which Florian consistently elicited students collectively to judge answers. In turn 36, for example, Florian prompted a whole-class response to whether 'a symbol for aluminium (A) was correct or not'. Students gave their verdict through simple yes/no choral affirmation. On the surface, this practice may suggest that students are engaging in self and peer assessments through collective judgement of the correctness of answers. However, teachers sought collective judgement to gauge students' recall of the content covered.

> I asked them like that just to find out if the rest of the students in the class remember the correct answer exactly the way I taught them in the previous lessons. When I ask them 'is the answer given by your colleague correct?' When few of them respond, it means what? ... Most of them don't remember the material or they didn't revise it since then… (Florian, Post-observation interview).

The type of feedback in which teachers elaborated and built upon students' answers was uncommon. It was rare to find teachers prompting students to explain or justify their responses. This accords with the fact that teachers rarely asked thought-provoking questions that required students to express their views and perspectives.

Such questions would compel students to justify and elaborate on their answers, thereby developing their thinking skills. For teachers, however, answers that deviated from the mainstream subject knowledge would signify a lack of revision rather than alternative interpretations of the subject content.

Indeed, teachers established the correctness of students' responses by instinctively comparing answers with the textbook knowledge they delivered. When asked on what basis they evaluated the correctness of students' responses, they unanimously mentioned textbooks, their own knowledge and lesson notes.

> If a student's answer is correct, how do I determine? There is a book! …is not that what I am teaching is coming from my brain. No I took from somewhere, I copied it from a book may be, so if the answer is the same as the one in a book then that's correct isn't it (Alex, Post-observation interview).

This supports the notion that teachers believe textbooks to be a criterion for judging the accuracy of students' answers. Some teachers, however, relied on their own knowledge base in deciding the accuracy of answers.

> What I am teaching is not new to me I mostly learned the same… I know which answer is correct and which is not. They should trust me, as their teacher, I know these things (Nuru, Post-observation interview).

Generally, textbooks and teachers are important knowledge sources and are therefore criteria against which the teachers can check students' mastery of a subject. However, rejecting or accepting students' responses based on similarity to established knowledge sources narrows learning to the acquisition of textbook content. Further, negotiating the accuracy of students' answers can be an opportunity to gain insights into students' thinking, and could lead to better answers and deeper learning if correctly used. In what follows, I describe classroom interactions.

7.2.5 Classroom interaction

Classroom talk is an important aspect of teaching that may reflect teachers' beliefs. Participants, content, and format of talk are all valuable aspects in which the beliefs underlying teachers' practices may be visible. In this section, I present results of my analysis of teacher–student interactions in the 18 selected lessons.

Types of interactions

Table 7.6 shows the types and purposes of interactions. The results show that teachers mostly interacted with the whole class rather than with groups or individuals. On average, approximately 58 (73.06%) of the 79 interactions involved teacher and whole class. In comparison, teacher–group and teacher–individual interactions combined constituted only 15.6% of all interactions. This suggests that, when teachers teach, they focus on the whole class instead of on individual learners or small groups. This predominance of teacher–class interactions may reflect a traditional classroom organisation (see section 7.1.2) in which students are seated in rows, one behind the other, with little or no space between the rows. This type of classroom setup precludes teacher–individual, teacher–group and individual–individual interactions.

Table 7.6: Types and purposes of interactions in the 18 lessons

Purpose	**Type of interaction**						
	T-C	**T-G**	**T-I**	**I-C**	**I-G**	**I-I**	**Total**
Instructional	916	66	78	78	31	27	1196
Routine	39	6	10	24	0	0	79
Monitoring	74	5	37	0	0	0	116
Discipline	0	10	6	0	0	0	16
Other	7	0	4	0	0	0	11
Sum	**1036**	**87**	**135**	**102**	**31**	**27**	**1418**
Average	**58**	**5**	**8**	**6**	**2**	**2**	**79**

Key: T-C=Teacher–Class, T-G=Teacher–Group, T-I=Teacher–Individual,
I-C=Individual–Class, I-G=Individual–Group, I-I=Individual–Individual

Most teacher–class interactions focused on the content of the lesson and tasks. Interaction pattern varied with lesson stage. During the introduction phase, teachers mostly initiated interactions through questions about the content of the previous lesson (see turns 5 and 7, box 7. 30). Students' responses comprised recall of the content of the previous lesson (turns 8, 10, 12 and 14, box 7.30), and teacher feedback comprised simple affirmation to signify acceptance or rejection of answers. Afterwards, teachers initiated the next interaction cycle.

Utterances varied in length, but generally, brief whole-class choral or individual responses of one to three words were widespread. Teachers' verbal utterances during the presentation phase tended to be longer and more elaborate than the introduction and culmination phases. In the presentation phase, teachers delivered content, which necessitated giving elaborate descriptions.

Box 7.30: Excerpt from a Form I Chemistry lesson by Deman

(5)Teacher: Then, turned to students and asked 'last time we studied a topic known as...? (*Cued intonation prompting whole class choral response)*

(6)Students: Mostly silent, few raised hands.

(7)Teacher: The last topic we discussed. We ended was about...? (*Cued intonation prompting whole class choral response*).

(8)Students: Uneven choral answers 'matter part B, matter part B'.

(9)Teacher: Picked on 'it was about matter party...? (*Cued intonation*).

(10)Students: Recited 'B'.

(11)Teacher: Joined the chant 'B'. And on this topic of matter part B we saw a lot of things. We saw a lot of?

(12)Students: Chanted 'things'.

(13)Teacher: We saw many things. And after matter part B there is only one topic left which we are going to start today. But, let's again revise on matter part...?

(14)Students: Chanted 'B'.

(15)Teacher: And on matter part B, we dealt with what we call mixtures, compounds and elements. And we said [pause] we said mixtures can be in different forms. Mixtures can be in different...? (*Cued intonation*).

(16)Students: Chanted 'form'.

(17)Teacher: So mixture can be in form of dash______ or dash_______ or dash____?

(18)Students: Silent

(19)Teacher: Repeated, 'mixture can be in form of___? Eeeeh you!' (*Picked a student to answer*).

(20)Student1: Stood up and remained silent (*after few seconds of silence*).

(21)Students: Others raised hands (*seemingly, they realised a selected students could not answer*).

(22)Teacher: Silently selected another student.

(23)Student 2: Stood up and answered 'suspension form'.

(24)Teacher: Mixture can be in form of suspension or...? (*Cued for the next answer*).

(25)Students: Silent.

Likewise, during the presentation phase, teachers initiated interactions by asking questions. They asked questions on both the previous lessons and the 'new lesson' they were teaching. A notable pattern in this phase was that teachers prompted students to recite content they had just delivered. For example, in turn 47 in box 7.31, Nuru asked students to name organisms that reproduce by 'budding', which she had earlier listed when presenting (turn 43). This made the classroom talk ritualised and repetitive with an established and shared sense of what was needed to happen next.

Box 7.31: Extract from a Form IV Biology lesson by Nuru

(43) Teacher: Good. Examples of organisms that reproduce by budding include Yeast, Hydra and some Annelids. *(She then wrote a definition of budding and description on how budding occurred including organisms that reproduce via budding).* Budding is a form of asexual reproduction in which a new individual organism develops as an outgrowth (Bud) from the parent... Later a new organism detaches itself from the parent and become independent.

(44) Students: Intensively wrote notes as the teacher continued writing on the chalkboard.

(45) Teacher: Re-reads everything she wrote underlining key words and phrases to be remembered. She finalized her explanation with a question made of unfinished sentence: 'Later a new organism detaches itself from the parent and become___?'

(46) Students: Chanted 'independent'

(47) Teacher: I said what organisms reproduce in this way? (*Names were on the chalkboard written as notes).*

As shown in table 7.6, there were more teacher–individual interactions than teacher–group interactions. This suggests that most learning activities were solitary thus collaborative small group learning activities were rare. On average, interactions involving students themselves (I-C, I-G, I-I) accounted for about 11% of all interactions. This was much less than the interactions involving teacher and students (T-C, T-G, T-I), which constituted around 89% of all interactions. This further confirms the solitary nature of the learning activities in which students rarely interacted among themselves. When students interacted among themselves, they did so with the whole class rather than with individuals or groups. This happened when teachers occasionally called them to the front to share their solutions or to illustrate concepts.

When interacting with the whole class, students imitated teachers' style of teaching in which they interspersed explanations with affirmative questions or question tags. A segment of a Form II Chemistry lesson by Florian (box 7.32) illustrates how one student who presented the work that had been done by his group ('Group 3 presenter' in box 7.32) interacted with the whole class. This involved verbal presentation of the task performed by the group (turns 112, 114 and 116, box 7.32). Group presenters combined this with short closed factual questions, which prompted a whole-class choral response (turns 113, 115, 117, 119 and 121, box 7.32). Much of these practices reflected the way teachers taught. This also demonstrates 'apprenticeship of observation' in which young learners develop images of desirable models of teaching during schooling and reproduce such models in their own practices when they become teachers.

Box 7.32: Student–class interaction mimicking teachers' teaching style (Florian, Form II Chemistry)

(110) Group 3 presenter: Walked to the chalkboard, picked a chalk and greeted 'good morning class. In our discussion…'

[*Hardly audible, teacher intervened*]

(112) Group 3 presenter: In our discussion [?] the question is why atoms bond? In our group discussion we said that atoms bond [?] an atom bond in order to be stable (*turned to the board and wrote*) 'atom bond in order to be stable (*Spoke as he wrote, turned to the class*) that is other atoms are not stable, that is why what?' (*Cued intonation*).

Students: Silent.

Group 3 presenter: They combine, in order to become what?

(113) Students: Chanted 'stable'.

(114) Group 3 presenter: Joined the chant 'in order to become stable. Now let me give you an example, let me give you an example, sodium… (*turned to the chalkboard and wrote Na*) Sodium is how much?

(115) Students: Some, especially group members chanted 'eleventh'

(116) Group 3 presenter: Yeah eleventh. So, it becomes 2:8:7 (*wrote as he talked*) then he drew the electronic configuration of chlorine showing electrons around an atom *(this involved drawing small circles around one another to represent shells depending on the number of electrons an atom poses in its shells).* He counted the number of electrons he drew 'two, four, six, eight… Now! We said metal (*pronounced 'Meta'*) … all metals (*pointed at Na*) are what?

(117) Students: Few chanted 'losers'

(118) Group 3 presenter: eeeh? (*Prompted more to join a chant*).

(119) Students: Recited 'losers'.

(120) Group 3 presenter: But all non-metals are what? (*Pointed at Cl*)

(121) Students: Recited 'gainers'.

(122) Group 3 presenter: This one (Sodium) is unstable because of what? It is exceeded by one what? (*Pointed at electrons*). This is called what? (*Turned to students*), if you really remember, let one of you tell me, what this is called?

(123) Students: Some chanted 'electron'

(124) Group 3 presenter: Eeeeh!

(125) Students: In unison, they replied 'electron'.

Purpose of interaction

The results in table 7.6 show that over 84% of all interactions were for instructional purposes. Monitoring interactions closely followed. Whole-class monitoring was widespread, while monitoring individual students was less common, and monitoring groups was rare. This coincided with the predominance of whole-class teaching in which students tended to be obedient and docile towards teachers to allow smooth knowledge transfer. Consequently, disciplinary interactions involving scolding, reprimanding and calling the names of disruptive students were minimal. Deviation from this norm was in the form of passive resistance where a student could remain silent when asked questions if they did not wish to speak. Often, students prompted to answer questions stood up to show obedience, but remained silent. This habit may reflect respect for teachers' authority.

I recorded 442 incidents in which teachers attempted to initiate interactions but students remained reluctant to respond. I counted these as utterances without responses and feedback. These, combined with 1418 interactions that had initiation, response and feedback, or initiation and response, would amount to 1860 interactions initiated by the teachers. Therefore, interactions initiated unsuccessfully by the teachers constituted over 23% of actual interactions attempted. For the attempted but unsuccessful interactions, students mostly remained silent, and the teachers either gave up or answered the questions themselves.

Interactions in different phases of the lesson

Interactions varied slightly between different phases of the lessons. Of the 18 lessons selected for analysis, 12 had clearly demarcated introduction, presentation and conclusion phases. I confined interaction analysis 'by lesson phase' to these lessons. Table 7.7 shows the results of interactions in different stages of the lessons.

Table 7.7: Classroom interaction in different phases of the lesson

Type of interaction	Lesson phase			
	Introduction	Presentation	Culmination	Total
T-C	414	407	26	847
T-G	21	56	0	77
T-I	37	80	0	117
I-C	11	87	0	98
I-G	16	15	0	31
I-I	3	24	0	27
Total	**502**	**669**	**26**	**1197**

Key: T-C=Teacher–Class, T-G=Teacher–Group, T-I=Teacher–Individual, I-C=Individual–Class, I-G=Individual–Group, I-I=Individual–Individual

The results in table 7.7 indicate that teachers interacted almost equally during the introduction and presentation phases, but less during the lesson culmination. In all phases of the lessons, teachers interacted most with the whole class rather than with groups or individual students. This is symbolic of teaching that involved teacher-led talk interspersed with closed factual questions that sought choral responses. Further, teacher–group and teacher–individual interactions were slightly higher during the presentation stage than during the introduction and culmination phases. This reflects the few teacher–group interactions I observed in Florian's lessons and teacher–individual interactions when teachers called students to the front of the class to share their ideas.

7.3 Chapter summary

In this chapter, I analysed science teachers' practices to gain insights into the ways in which their beliefs about science knowledge, teaching and learning manifests in the actual classroom teaching. I found that both studied schools have oblong-shaped classroom designs, with students' chairs and tables traditionally organised in rows, all facing the chalkboard and the teacher. Each school has science laboratories equipped with basic facilities. The students sit in rows, one behind the other, interacting with the teacher as a whole class, but rarely with each other. This classroom organisation symbolises teaching in which knowledge flows from teacher to students.

I found that lessons have precise and predictable framing in terms of time and content. Most lessons have three distinct phases: introduction, presentation and culmination. In the introduction phase, question-and-answer episodes prevailed and are intended to ascertain the amount of subject content that the students can recall. Further, teacher-led delivery of content knowledge interspersed with factual questions intended to prompt students to recite content dominates the presentation phase. Science practical lessons have a slightly different structure, but these focuses solely on requiring students to practise solving past practical exam papers as opposed to pursuing scientific questions of interest to the students.

Most importantly, learning tasks promote the acquisition of textbook knowledge. Even when a task requires conceptual understanding, by its nature the teachers confine their teaching to the simple transmission of facts. In keeping with this, a task's cognitive demands were largely constrained to the recall of textbook facts.

Students spend a substantial part of instructional time seated and listening to teacher talk. In the lessons observed, listening accounted for 45% of learning activities compared with interactive activities such as groups and plenary discussions, which accounted for less than 1% of all learning activities. These and other interactive learning activities such as calling students to the front of the class to share their ideas or asking them to observe real objects to illustrate concepts were occasional. Consistently, over 70% of all observed interactions involved the teacher interacting with the whole class, compared with other forms of interactions, which accounted for less than 30% of all observed interactions.

Lastly, the teachers predominantly ask closed factual questions to elicit short affirmative, one-word or itemised answers. They mainly ask questions to test students' recall of the content knowledge they had delivered. On average, in the lessons observed, closed factual questions, which required single or fixed list of answers, accounted for 85% of all questions asked.

While occasional activities such as showing real objects to demonstrate concepts, calling students to the front to share ideas, question - and - answer and similar active learning strategies may reflect 'procedural forms' of learner-centred pedagogy (Brodie et al., 2002), many of the practices described in this chapter largely symbolise teacher-centred teaching (Magnusson et al., 1999). Further, these practices largely reflect the beliefs about science knowledge, teaching and learning that these teachers professed. Although some of the teachers professed sophisticated accounts of knowledge, teaching, and learning that closely matched learner-centred teaching, their practices did not reflect such beliefs. This suggests a gap between beliefs and practices, which I discuss in the next chapter.

Chapter 8: Discussion, Conclusion, and Recommendations

8.0 Introduction

This chapter discusses how science teachers' beliefs are manifested in their teaching practices and the implications for pedagogical reforms in Tanzania. To establish this relationship, I discuss the consistencies and inconsistencies between teachers' beliefs about science knowledge, teaching and learning and their teaching practices. Further, using the theoretical concepts of core and peripheral beliefs, beliefs connectedness and relatedness with the contextual conditions, I discuss why some teachers could not enact their beliefs in practice. I attempt to explain the inconsistency between science teachers' beliefs and the basic principles of learner-centred pedagogy, highlighting how this might explain teachers' uptake of pedagogical reforms in Tanzania. Finally, I offer suggestions for teacher educators and policy makers based on the key insights from this study.

8.1 Teachers' beliefs and practices: Consistency

It is widely acknowledged that teachers' beliefs reflect the actual nature of teaching in the classroom (Fives and Buehl, 2016; Kagan, 1992). In chapter 5, I described science teachers' beliefs. I found that they largely held congruent 'assemblage' of beliefs I identified as 'traditional beliefs' about science knowledge, teaching and learning (Glackin, 2016; Tsai, 2002). In theory, traditional beliefs are associated with traditional teacher-centred practices (Kang and Wallace, 2005; Mansour, 2013). Further, two teachers expressed 'constructivist beliefs' about teaching and learning in addition to their mainstream beliefs common to the rest of the teachers. Constructivist beliefs are closely aligned with learner-centred teaching and learning (Kang and Wallace, 2005; Mansour, 2013). In chapter 7, I described science teachers' classroom practices. I found that much of the classroom teaching practices reflect transmissive teacher-centred teaching. In this section, I discuss how teachers' beliefs manifest in the key elements of their classroom practices. Specifically, I highlight teachers' practices that dovetail with their particular beliefs about science knowledge, teaching and learning.

8.1.1 Beliefs underlying classroom organisation

The classroom and how its basic elements are organised and used reveal teachers' various assumptions about knowledge, teaching and learning. First, the oblong-shaped classroom with students sitting in rows, one behind another, all facing the chalkboard and the teacher, suggests that knowledge flows from teacher to students (see figures 7.1–7.4). This unidirectional focus on teacher and chalkboard is consistent with the perception of the teacher as a source and dispenser of knowledge in the classroom. Students sit in well-organised rows of desks so that they can focus on, see and hear the teacher, thereby maximising knowledge transmission. In this context, the instructional goal is to ensure that the students acquire the knowledge the teacher delivers, by attentively listening and copying notes.

Most importantly, the classroom organisation in which students sit neatly in rows all facing the front helps teachers to monitor and control the class (Brown and Melear, 2006). Indeed, the teachers demonstrate 'withitness' by positioning themselves where they can see all the students. They maintain eye contact as they scan the entire class to check students' behaviours. Such practices are consistent with teachers' belief in classroom rules and management strategies to enforce order and compliance and enhance respect for authority (Alexander, 2001).

Although teachers are not fully in control of the 'oblong-shaped architectural design' itself, they enact their beliefs in a traditional classroom organisation through the seating arrangement they choose for their students. Teachers and students have the choice of a desirable seating arrangement that fits instructional goals. However, as I showed in section 7.1.3, teachers occasionally teach ‘theory lessons’ in the laboratories where the design of the room allows a seating arrangement that could optimise interactive teaching and learning (see figure 7.4). Even in this context, the default seating plan in which students sit in rows, all facing the teacher at the front, prevails. This preference for a conventional seating arrangement creates conditions consistent with a belief that knowledge must flow from teacher to students. A seating arrangement in which all students face the teacher, ready to listen to teacher talk and copy notes from the chalkboard, helps to position the teacher as an authority. It symbolises a hierarchical knowledge structure consistent with beliefs in transmissive teaching and coheres with views of teaching as conveying and of learning as assimilating knowledge. This accords with Mansour (2013), who observed that teachers holding traditional beliefs organise their classrooms conventionally in long rows of desks all facing the chalkboard and exercise control to maintain obedience. Such teachers prefer content delivery and rarely use teaching aids even when they are available in schools. In what follows, I discuss lesson structure, uncovering further connections between teachers’ beliefs and practices.

8.1.2 Beliefs reflected in the lesson structure

A precisely framed lesson structure with regular periods and routine activities reflects a belief in impersonal learning in which knowledge pre-exists and is detached from the ‘person’ of the learner. At the core of a strongly framed lesson is the assumption that all students, regardless of their differences, learn the same segment of the curriculum uniformly, thereby de-emphasising negotiation of personal meaning making. That is, all students equally comprehend the same content, at the same pace, and attain the same proficiency level (Alexander, 2001;

Dancy and Henderson, 2007). Such lesson framing merges well with teachers' conceptions of science as inert content that they deliver in a standard way and which every learner must make an effort to acquire. It is consistent with a belief that students are essentially not co-constructors of knowledge, and their personal experiences and perspectives have little significance.

Further, the verbal presentation of textbook knowledge interspersed with choral answers elicited using cued questions serves to reinforce the teachers' beliefs in transmissive teaching, which is consistent with the idea that knowledge travels from a higher authority to a lesser one. Much of what the teachers believe and how they act in their classrooms reflects their views that scientific knowledge is 'sacred' and that students' responsibility is to receive and assimilate this knowledge instead of interrogating it (Mansour, 2013). Above all, structural constraints exist, including government circulars, syllabi, and timetables, which seem to reinforce and legitimise teachers' beliefs system and the way in which they organised teaching.

8.1.3 Beliefs manifested in the lesson tasks

How the teachers organise lesson tasks and the type of knowledge and cognitive demands the tasks seek to promote are consistent with their conceptions of scientific knowledge as discrete chunks of facts that students straightforwardly add onto what they already know (Alexander, 2001; Schommer-Aikins, 2004). Teachers' beliefs manifested in how they organised lesson tasks into closed disconnected episodes and presented topics without showing connections that would have helped students to construct comprehensive and cohesive understanding.

Further, the prevalence of learning tasks that mainly promoted the acquisition of factual knowledge is consistent with the teachers' conceptions of learning as acquiring ready-made knowledge (Tsai, 2002). Even when a task required conceptual or procedural engagement by its nature, teachers lowered the task's cognitive demand by transmitting textbook knowledge and asking closed factual questions consistent with their 'cumulative' perceptions of learning. The effect was to project the supremacy of the textbook and restrict students from seeking knowledge from other sources. By limiting learning tasks to simple assimilation and recall of textbook knowledge, teachers were sending a message to students that the scientific knowledge they were encountering was not up for critical reflection and interrogation. It is not surprising that students passively received and accepted knowledge in the form teachers presented it without interpreting, interrogating or negotiating its meaning.

8.1.4 Beliefs manifested in the lesson activities and classroom interactions

The predominance of passive learning activities, including listening to teacher talk, recitation and copying notes, in the observed lessons corroborates teachers' espousal of such activities when describing their 'ideal' lessons. Beliefs underlying such preference for passive learning activities are that students should take what teachers present as authority and that the students' role is therefore to memorise the knowledge, often through repetitive recitation. Asking factual questions that elicit whole-class choral responses and recitations appears to reinforce the model of learning the teachers espoused. Even on the rare occasions where teachers used real objects in demonstration lessons, this was essentially to persuade students of the veridicality of scientific truths. Engaging students in active interpretation, critiquing, and negotiating scientific ideas was uncommon and consistent with teachers' views of learning as simply looking and listening (Bruner, 1996).

Teachers' preference for interacting with a whole class rather than with individuals reinforces their belief that the best way to deliver science knowledge is through a standard form for all students, irrespective of their previous knowledge, to receive it unquestionably. Teacher–class interaction becomes logically an efficient strategy to achieve standard knowledge delivery, while more individualised interactions become less efficient, consistent with teachers' understanding of how science is acquired. Indeed, studies in other contexts suggest that such teachers de-emphasise classroom interactions because, for them, knowledge is detached from students' thinking (Dancy and Henderson, 2007). In that case, learning interactions to share and negotiate interpretations become needless because the primary concern is to convey knowledge and test students' recall via cued choral answers (Brophy, 2002).

8.1.5 Beliefs reflected in teachers' questioning practices

Teachers enacted their beliefs through the type of questions they asked, answers they sought and feedback they gave following students' responses. Asking closed factual questions and seeking single predetermined fixed answers known beforehand to the teacher is indicative of a 'right or wrong answer' approach to acquiring scientific knowledge. Such practice is consistent with the teachers' conceptions of scientific questions and problems as having simple right or wrong solutions. Teachers consider such solutions as verified truths and expect students to memorise and remember them. Therefore, probing questions that elicit divergent ideas and viewpoints become less appealing because these are not consistent with the aim of testing students' recall of facts.

The belief that legitimate knowledge constitutes objective facts is evident in the way in which teachers asked questions that largely sought clear-cut true or false responses from students. Questions inviting students to express their personal understanding are less attractive because they contradict teachers' conceptions of science knowledge and how it should be acquired. Such questions could prompt speculative, partially correct or less clear-cut answers.

It is clear from the evidence that when ideas different from the textbook knowledge emerged during a lesson, teachers either rejected or ignored them and, instead, redirected students' attention to what was prescribed in the science textbook. This exemplified teachers' belief in textbooks as a standard knowledge source. For teachers, the quantity of knowledge a learner can retrieve demonstrates learning proficiency (Kang and Wallace, 2005; Park et al., 2010).

Moreover, drilling students to memorise science knowledge by asking them exam-style questions accords with teachers' conceptions of teaching as facilitating the acquisition of the knowledge that students need to pass exams. By requiring students to rehearse answers in response to typical items drawn from past exams, the teachers are simply enacting their own vision of successful learning as reproducing the necessary knowledge to pass exams. Furthermore, teachers' experiences of marking national exams appear to have reinforced their instinctive power to deduce possible future exam questions, consistent with their belief that successful learning is about how much knowledge students can store and regurgitate to achieve exam success.

8.1.6 Beliefs underlying feedback patterns

It is evident that because the teachers see themselves as knowledge authorities and as benchmarks for deciding the validity of students' ideas, probing and negotiating evidence and justifications for answers are of little interest. Negotiating truth becomes needless, and feedback in the instructional process is simply to ascertain whether students' ideas and answers align with what the teacher considers a standard 'truth'.

For the teachers, the validity of an answer is not subject to the strength of the supporting evidence and justifications, but is a clear-cut judgement based on the extent to which an answer emulates the teacher or textbook knowledge, as previously argued. Therefore, negotiating answers by considering evidence and justifications that would involve elaborate feedback become needless. This explains why the teachers rarely engaged students in discussing evidence and justifications that supports their answers.

Lastly, the use of instructional strategies involving differential treatments of students, frequently asking only a few students who were considered to be intelligent, and publicly rewarding and exclaiming their inborn attributes, is consistent with teachers' beliefs in the fixity of the ability to learn science, which they accorded these few students. In this case, the ability to produce correct answers serves as markers of intelligence and shape the teachers' expectations for students.

8.1.7 Beliefs underlying confirmatory practical work

Teachers' conception of science as a body of facts resulting from the structured rational observation of the natural world was notable in the recipe-type practical work, in which they precisely specified procedures that students had to follow to obtain results that verify the facts and principles already taught. This model of practical work reflects a view of scientific investigation as a mere imitation of 'established methods' to verify established knowledge. Practical work that does not offer students the opportunity to pose questions, hypothesise and negotiate evidence narrows inquiry learning to confirming theoretical points and predetermined solutions. Set against teachers' views of scientific inquiry as reproduction, there is little inclination to view practical work as anything other than re-establishing bodies of scientific knowledge.

How teachers enacted their vision of scientific inquiry was more evident when students produced results that diverged from the predetermined solutions expected by the teachers. In such cases, teachers strived to audit whether the students had correctly followed the prescribed procedures and whether the apparatus used had functioned properly. Demonstrating what students should have done and asking them to imitate and repeat the experiment to arrive at predetermined answers is reinforced by teachers' conceptions of scientific inquiry.

When teachers discourage students from imagining, and giving divergent interpretation of results, they collect during laboratory work, this has the potential to structure their thinking towards producing evidence and interpreting it in a way that suggests that there can be a single 'truth' in scientific knowledge. For example, attributing divergent results collected by the students during experiments to faulty equipment or to a failure to follow the recipe, instead of alternative interpretations or the result of pursuing a different variable, reinforces the illusion of knowledge in science as indisputable (Tsai, 2002). Scientific inquiry is inevitably messy and involves negotiating established procedures and interpretations of results that can make conclusions indeterminate or require further inquiry (Brown and Melear, 2006).

Because, for the teachers, scientific knowledge is absolute and pre-exists students, logically what students can achieve through practical work is simply to generate evidence that confirms it. Thus, it is difficult for teachers to see practical work as a way of generating evidence that students could use to construct or reconstruct knowledge or new ideas about scientific phenomena. The opportunity to use practical work to exemplify scientific inquiry process and offer plausible explanations for results whether expected or not is avoided. This deprives students of the opportunity to be critical and reflective in how they interpret scientific knowledge. In effect, using practical work to demonstrate the veridicality of scientific knowledge instead of engaging students in solving real problems and modelling scientific investigations to build their scientific thinking is not part of the discourse of learning science through experimentation. Pursuing such broader goals of practical work would be inconsistent with teachers' views of learning science as passing exams. However, teachers' use of practical work to solve questions drawn from past practical exams projects the priority of ensuring that students pass exams. Although confirmatory experiments are of limited learning value (Tsai, 2002), the teachers perceive them to be effective for preparing students for practical examinations.

To sum up, in this section, I have discussed how science teachers' beliefs manifested in actual classroom practice. Overall, teachers' practices largely reflect their 'traditional beliefs' about scientific knowledge, teaching and learning. This suggests that their beliefs may partly explain their observed teaching practices. In particular, this study and others (Glackin, 2016; Kang, 2008; Kang and Wallace, 2005; Levitt, 2002; Mansour, 2013; Park et al., 2010) have demonstrated that traditional teacher-centred teaching may be partly rooted in teachers' beliefs and is simultaneously reinforced by them. However, this association between beliefs and practices appears to diminish when teachers espouse sophisticated beliefs about knowledge, teaching and learning that are aligned with a learner-centred pedagogy. I discuss this inconsistency in the next sections.

8.2 Teachers' beliefs and practices: Inconsistency

Teachers can espouse beliefs about science, teaching and learning that are supportive of learner-centred pedagogy, yet confine their actual practices to teacher-centred approaches that are inconsistent with their beliefs (Bryan, 2012).

This was clearly exemplified in two teachers, John and Alex, who professed constructivist beliefs supportive of learner-centred teaching, yet they rarely enacted such beliefs during actual teaching. Even when they attempted to enact such beliefs, they did so temporarily and in a way that reflected ‘procedural forms’ as opposed to the principles that underlie learner-centred pedagogy. In what follows, I discuss how the nature of the belief itself as well as the social and contextual variables might explain such inconsistencies.

Although John and Alex advocated teaching strategies that facilitate engagement and understanding, through hands-on activities and giving them familiar examples to link knowledge to real life, they rarely enacted such strategies during actual lessons. For example, when describing his ideal lesson, John advocated ‘using plants’ to help students understand ‘scattered and ring-like distribution of vascular bundles’ that distinguishes monocot from dicot plants. Contrary to his belief, in his actual lesson, John verbally explained the ‘structure and function of vascular bundles’ without engaging students in observing such structures in real plants. This could have involved observing the cross-section of a monocot and dicot stem under a microscope to locate and identify patterns of vascular bundles. Supplies for this simple activity, including microscope and hand lenses, were available in the school laboratory. In addition, while John espoused sequencing and connecting topics to help students relate and understand them, he did not link his lesson on ‘structure and function of vascular bundles in plant transport of materials’ to similar concepts used to classify plants into ‘dicots and monocots’. Such practices were inconsistent with John’s espoused beliefs.

While Alex believed that teaching science should emphasise practical activities and promote students’ understanding, the way he actually organised practical work was more consistent with his conception of teaching as preparing students for final practical examinations. Alex exemplified his views in how he prescribed experimental procedures for the students to follow to arrive at model exam answers, and intervened whenever students obtained divergent results, signalling them to align instead with exam requirements.

Similarly, while Florian and Nuru espoused views of science as tentative knowledge subject to errors and review when further evidence is discovered (see section 5.1.3), such views were inconsistent with the way they actually presented scientific knowledge when teaching. Like others, these teachers encouraged students to receive knowledge they presented as absolute facts. Discouraging students from questioning the verity of textbook or teacher knowledge and constraining them from providing multiple accounts of phenomena suggest that these teachers were more inclined to their absolutist conceptions of science. In addition, asking factual questions, seeking clear-cut answers and judging these as either right or wrong without probing for justifications demonstrate that knowledge was not negotiated relative to evidence. While such practices partly indicate that the teachers are teaching contrary to their beliefs, it may be that the curriculum and exams are structuring their teaching by limiting the space available for the teachers to engage students in interrogating and negotiating established knowledge (see section 8.3 for further discussion).

Teaching through interactive strategies such as group activities and demonstrations extemporarily or in ways that optimise content delivery suggests that the teachers are either not fully committed to using such strategies or structurally constrained to promote deeper learning. For example, providing students with books and organising group discussions in the first lesson, yet avoiding these practices in subsequent lessons, suggests that teaching through activities was not habitual. Abandoning such practices during subsequent lessons, implies that such practices were interludes and inconsistent with their core beliefs in transmissive teaching, to which they were committed to enact habitually.

Overall, despite some teachers espousing sophisticated beliefs about science, teaching and learning that appeared to be supportive of learner-centred pedagogy, such beliefs were not evident in their actual practices. Researchers in other contexts (Kang and Wallace, 2005; Mansour, 2013; Tsai, 2002; Waters-Adams, 2006) have also observed similar incongruity between teachers' espoused beliefs and their actual practices. I attempt to explain these inconsistencies in the next section.

8.2.1 Teachers' beliefs and practices: Why incongruous?

In theory, teachers teach in accordance with their beliefs (Fang, 1996; Glackin, 2016; Hutner and Markman, 2016). However, as discussed in section 8.2, teachers may hold beliefs aligned with a learner-centred pedagogy, yet their actual teaching may be inconsistent with their beliefs. Using the theoretical literature, I attempt to explain this belief–practice inconsistency and why some teachers enacted one set of held beliefs over another.

As described in section 4.2, beliefs are web-like mental representations of reality that form part of human cognitive structure. Teachers hold beliefs along the core-periphery dimensions (Hutner and Markman, 2016; Rokeach, 1968). Core beliefs are strongly related to other beliefs and have been frequently used in past cognitive processes and are thus resistant to change. For a belief to manifest in practice, it must be active during the cognitive process that produces the practice (Hutner and Markman, 2016). In the context of this study, for example, for teachers to teach using learner-centred strategies such as group work, they must activate or prioritise beliefs supporting a learner-centred pedagogy. However, in theory, not all beliefs held in a person's memory are activated during a particular cognitive process, because there exists only a limited 'energy' for activation (Hutner and Markman, 2016). Based on this line of thought, it is possible for teachers to hold two sets of beliefs, such as realist and relativist beliefs about knowledge, and yet prioritise only one set of beliefs that support a particular practice and hold the rest in abeyance. In this context, it is possible that teachers often activate beliefs that support teacher-centred practices but not beliefs that are aligned with learner-centred teaching. Why and how is this possible?

In theory, core beliefs are more readily activated than the rest of the beliefs that the teachers hold. According to Pajares (1992), the earlier the belief is incorporated into the beliefs structure, the longer that belief is used and therefore the more robust and important it becomes to the individual holding it. Such beliefs are core to the individual holding them. In the present study's context, traditional beliefs about 'how people learn' or 'how people teach others' or even 'who possess the knowledge to be learned' are incorporated into the teachers' beliefs structure early, during childhood and early schooling, as explained in chapter 6. In contrast, the teachers acquire beliefs that are supportive of a learner-centred pedagogy later, during initial or in-service teacher training. Therefore, traditional beliefs are core and inherently important to the teachers because they have grown up with and frequently used them in past cognitive processes (Hutner and Markman, 2016). The teachers, for example, grew up in a cultural context where parents encouraged children to indisputably assimilate habits of thoughts and of conduct that adults prescribed to children.

From this perspective, teachers who strongly believe in a particular teaching approach, either because they are strongly committed to it or they have frequently used it in their previous teaching, are more likely to draw upon such practices than other teaching practices. Five of the six teachers in this study had more than five years of teaching experience and had been schooled in an education system where teacher-centred teaching was the norm. Thus, they are likely to be committed to beliefs that are aligned with a teacher-centred teaching that they experienced through 'apprentice of observation' during their own schooling (Lortie, 2002). Most importantly, some teachers taught science as high-school graduates prior to formal training on learner-centred pedagogy. It is more likely than not that such pre-college teaching drew on beliefs consistent with a teacher-centred pedagogy. All these factors may have made it possible for the teachers to hold beliefs consistent with both teaching approaches and yet enact beliefs consistent with a teacher-centred pedagogy.

Educational structures and contextual constraints also validate traditional beliefs that are supportive of a teacher-centred pedagogy, thereby contributing to their tenacity and vigour. For example, even when the teachers espouse 'constructivist beliefs' and are committed to implementing inquiry learning and giving students the opportunity to reflect and query knowledge, school structures such as the curriculum, exams and timetables may be unsupportive of this. This makes traditional beliefs more likely activated than otherwise, because they are closely related to or more applicable in the existing school structures (Hutner and Markman, 2016).

Before the government introduced a learner-centred pedagogy, school structures including classroom designs, curricula, exams and accountability systems were all appropriated to a traditional teacher-centred pedagogy. The purpose of schooling, for example, is mainly to promote acquisition of textbook knowledge and help students to pass exams. Such educational goals closely resonate with beliefs supportive of transmissive teaching, in which the aim is to deliver the mandated textbook content that students need to pass public examinations. In addition, textbooks portray science knowledge as facts that learners need to memorise rather than interrogate, question or reconstruct. Even after the reforms, the curricula, for example, remain content-overloaded, while exams are largely high stakes and misaligned with the envisioned learner-centred pedagogy (Semali and Mehta, 2012; Semali et al., 2015; Vavrus and Bartlett, 2012). Above all, the accountability structures largely hold teachers accountable (through rewards and sanctions) for students' acquisition of factual knowledge and scores in high-stakes exams (see section 6.5). Consequently, teachers strongly believe that the purpose of schooling is to help students to acquire textbook content, pass exams and progress with further education. This makes beliefs about the purpose of schooling closely aligned and coherent with beliefs underlying teacher-centred teaching.

Parents and school principals further reinforce teachers' focus on helping students to pass exams, thereby making beliefs in transmissive teaching more coherent with beliefs about the purpose of schooling. In theory, different belief sets that are related to each other in the beliefs structure, and beliefs socially shared between individuals in a community, are inherently core to the individuals holding them (Hutner and Markman, 2016; Pajares, 1992). In other words, when parents, colleagues, students and administrators share common beliefs about the 'purpose of learning as passing exams', such beliefs are inherently core to teachers teaching in the same school context.

Therefore, in the school context where powerful structures such as exams and curricula demand that teachers deliver expected content and help students pass exams, it is difficult to imagine how the teachers can enact pedagogies that promote deeper learning. It will take a lot of personal energy and commitment to sustain a learner-centred pedagogy if the structures do not reward and reinforce practices that signify constructivist beliefs. Within the 'community of practice', a teacher implementing such innovative practice would have to work against both the community and the structures that are unrewarding and devaluing learner-centred teaching. Thus, some teachers may suspend their beliefs in a learner-centred pedagogy because of 'countervailing' school structures.

Lastly, it is likely that the teachers consider transmissive whole-class teaching to be feasible in the Tanzania classroom context because it is characterised by a shortage of resources and large class sizes (Barrett, 2007; Vavrus, 2009). It is more practical to convey knowledge rather than to pay attention to individual learners' needs when a class size is large. Indeed, teachers who advocated learner-centred teaching but did not enact such practices in their actual teaching attributed their failure to contextual constraints including large class sizes and bureaucratic demands (Brown and Melear, 2006). However, this seems not to apply to Getamock, where conditions were better. But even in this context, a physics teacher in a class of 25 students at Getamock remained focused on content delivery similar to a teacher in a class of 80 students at Marera. In this case, bureaucratic demands for teachers to deliver expected content and help students pass exams could be reinforcing beliefs in transmissive teaching. I now exemplify how the interplay between beliefs and structural constraints might explain the inconsistencies between beliefs and practices portrayed by teachers in this study.

The first case is Nuru and Florian, who believe that scientific knowledge is both absolute and tentative, but they encouraged students to assimilate teacher and textbook knowledge as definitive accounts of the natural world. This means that their belief in the tentativeness of science was not enacted in actual practice. Instead, they stuck to and enacted their view of science as absolute knowledge, which demonstrates that this belief may be core to them. In other words, these teachers may be more enthused to an absolutist view of science instead of both. This is likely because, while growing up, Nuru and Florian had been socialised into receiving adults' knowledge and instructions as absolute truths. Their cultures prohibited children from querying adults' directives. Giving similar accounts about knowledge authority in Swahili culture[14], Hamminga (2005) observed that, in such cultures, society presumes that elders embody uncontested knowledge because of their longer life experiences. It is likely that these teachers have assimilated such cultural beliefs into their cognitive structures during childhood (Kresse, 2009). Consequently, these form their core beliefs, which are more influential and resistant to change than other beliefs.

Based on this line of argument, it is clear why the teachers have rejected the basic principles of learner-centred pedagogy that would require them to create space for students to question, and reconstruct the authoritative knowledge they teach. A pedagogy that allows students to query and interrogate teachers' knowledge would logically challenge their core and culturally rooted beliefs about knowledge. It might be difficult for the teachers to allow students to treat expert knowledge as tentative truths subject to query, because this fundamentally conflicts with their well-established cultural assumptions about knowledge. In addition, structural

[14] Swahili culture in this context mean the culture of people inhibiting Tanzania, Kenya, and Uganda.

constraints, including the examination system, that hold teachers accountable for their students’ knowledge of facts instead of deeper understanding may also explain why the teachers encouraged students to memorise textbook facts. In short, even if teachers believe that the knowledge in expert-authored textbooks is tentative and susceptible to critique and reconstruction, examinations that predominantly measure factual knowledge inevitably compels them to drill students to memorise facts for which they are accountable to know.

A second case is John and Alex, who advocated teaching and learning to facilitate students’ understanding using real objects and practical work, yet they were preoccupied with content delivery and drilling students using past practical examination questions. Social and contextual conditions, which I discussed in chapter 6, may account for such belief–practice inconsistency. Teachers’ enthusiasm to implement transmissive teaching may be the result of images of teaching they developed during their own schooling. The teachers may be modelling the practices of their schoolteachers whom they admired for demonstrating mastery and delivery of subject content. Most importantly, the teachers may be enacting beliefs in transmissive teaching to fulfil the expectations of students, parents, and school administrators, who expect them to deliver the mandated syllabus content.

Together, these examples demonstrate how school structures reinforce teachers to enact traditional beliefs that support a teacher-centred pedagogy even when teachers hold more than one set of contradictory beliefs. This accords with Mansour (2009), who observed that the social, cultural and contextual factors mediate and influence the magnitude of belief–practice consistency. In what follows, I discuss how teachers’ beliefs may have influenced the implementation of a learner-centred pedagogy.

8.3 The influence of beliefs on teachers' uptake of pedagogical reforms

Research on teacher beliefs widely acknowledges that, when science teachers' beliefs are incongruous with teaching reform ideals, teachers either reject the reforms or implement them superficially (Bryan, 2012; Yerrick et al., 1997). Conversely, when such principles underlying teaching reforms resonate with their beliefs, teachers are likely to implement reform ideals enthusiastically (Levitt, 2002). In this section, I discuss how science teachers' beliefs relate to the basic principles of learner-centred pedagogy presented in section 2.2.3. Further, I demonstrate how school structures mediate the influence of beliefs on teachers' adoption of pedagogical reforms, thereby sustaining teacher-centred teaching.

8.3.1 Teachers' beliefs and reform ideals: Duelling paradigms

To reform teaching from teacher-centred to learner-centred approaches inevitably needs change in teachers' deep-seated beliefs about what constitutes knowledge and how it should be taught, learned, and evaluated (Tabulawa, 2013). However, teachers in this study hold beliefs that largely contrast with the basic tenets of learner-centred pedagogy, which underlie the current curriculum in Tanzania.

Epistemological incongruity

What the teachers consider legitimate science knowledge is epistemologically antithetical to the assumptions about knowledge that underlie the Tanzanian curriculum. To start with, teachers view scientific knowledge as expert-proven objective accounts of natural phenomena free from personal presuppositions, imaginations, and creativity. This belief largely contrasts with constructivist conceptions of learning envisioned in the curriculum in which prior experiences, imaginations, reflections, and personal meaning-making are central. Teachers might be resisting embracing the ideas that students generate through activities, reflections and imaginations as legitimate knowledge because of their belief in objectivity. They may be reluctant to enact a principle that requires them to encourage students to 'construct' knowledge because such a principle conflicts with their conception of knowledge as something that is absolute, prefabricated and codified in textbooks.

Since the teachers view science as absolute truth, pedagogic modes that allow space for students to actively analyse, critique and improve knowledge as envisioned in the curriculum may be less acceptable to them (Bernstein, 2000). If knowledge is absolute, it is not subject to critique and change, thus it is needless to encourage investigative activities that produce evidence and alternative accounts that expand knowledge boundaries beyond the established frameworks. Creating space for students to investigate scientific problems that interest them and to generate alternative conclusions beyond the frameworks of authorised science may be less attractive to and conflict with teachers' epistemological stance. Conversely, teachers restricting practical work to verifying facts they have already taught through structured experiments, and auditing 'findings' that deviate from predetermined conclusions, demonstrate instructional strategies that are best aligned with their epistemological beliefs (Lemberger et al., 1999; Meyer et al., 1999; Park et al., 2010).

It is unlikely that the teachers will encourage students to interrogate authoritative knowledge the way the curriculum requires, because, for them, such knowledge is unquestionable. Instead, teachers are likely to resist a pedagogical principle that requires them to allow space for students to scrutinise 'established knowledge authorities', including themselves. Teachers are likely to see interrogating their knowledge as undermining their authority because they perceive themselves and textbooks to be omniscient knowledge sources (Hofer and Pintrich, 1997).

In the Tanzanian context, teachers may be rejecting a learner-centred pedagogy because it demands them to undermine their position of knowledge authority by acting as facilitators instead of dictating knowledge. Indeed, teachers indicated that students complained of them being shallow and incompetent whenever they attempted to cover up their identities as 'knowledge dispensers' by allowing students to hypothesise, explore topics and contribute ideas instead of giving them knowledge directly. This means that the envisioned role of a teacher acting as a 'guide on the side' than a 'sage on the stage' distorts the images of good teachers that students have constructed.

Together, the recognition, respect and cherish that students accorded teachers who showed proven subject mastery, and teachers' desire to demonstrate knowledge mastery, which legitimises their professional authority and identity, reinforce a transmissive teaching that pedagogical reforms aimed to transform. Alternatively, subject knowledge embodiment and delivery are indispensable attributes of 'being' a good teacher, and asking teachers to abandon transmissive teaching by 'acting' as facilitators denies them the space to prove subject mastery, thereby undermining their professional authority. Pedagogic principles requiring teachers to relegate control of the class by treating students as 'equals', allowing them to take charge of learning, is undermining the traditionally reverend power and authority of teacher as a source of knowledge.

Further, teachers' absolutist view of science as the pursuit of a single definitive truth – an account of natural phenomena that experts present in books and that teachers deliver in class – is antithetical to a pedagogical principle that emphasises teachers to encourage students to appreciate the validity of multiple accounts, solutions, and perspectives. While for teachers every scientific question or problem corresponds to one absolute answer, the curriculum requires them to open dialogue and consider competing alternative claims, including claims students may make from their everyday experiences. Under this scenario of epistemological mismatch, teachers prefer teaching consistent with their own core beliefs, suspending the curriculum ideals. Teachers' assessment feedback, for example, simply validated whether students' ideas were correct or incorrect. Such a pattern of feedback restricts the opportunity for debating, probing, justifying, extending ideas and considering alternative perspectives, which would have promoted a constructivist view of knowledge. Indeed, for teachers, it is needless to encourage students to contribute ideas and generate alternative accounts or solutions different from those of experts. Teachers may be partly drawing on hierarchical African cultural models that place children (students) in an inferior position that is not culturally considered to be a source of legitimate knowledge (Akyeampong, 2017; Tabulawa, 2013).

Further, a view that detaches knowledge from learners is incongruous with the principle of learning as meaningful knowledge construction. This is because the production of scientific knowledge itself inevitably involves negotiating the soundest interpretation of evidence under the influence of scientists' own presuppositions and creativity (Lederman, 2004). Teachers presenting science as a 'lifeless content' separate from the 'person' of the learner, and learning as accruing inert facts without personal interpretations and without connecting concepts to everyday experiences, conflict with learner-centred pedagogy. Further, emphasising the acquisition of uniform knowledge without considering individual needs and prior experiences militates against learner-centred pedagogy, which requires that teachers consider the individual needs of the learner even when teaching established facts. By sticking to their own views of science, teachers are inevitably ignoring the fact that learning is rarely uniform for everyone because the needs, interests and social contexts of learners often influence the interpretation of subject content.

Lastly, teachers viewing the content of science as belonging to discrete subject disciplines and emphasising strong boundaries between them contradicts a central pillar of learner-centred pedagogy, which is to promote a holistic understanding of science necessary for solving real-world problems. Boundary disputes were evident when teachers described content knowledge as belonging to individual subjects, dismissing the interconnections between them. Considering such conceptions of the structure of scientific knowledge, it is difficult to see how teachers can promote personal sense-making, which inevitably involves learners reorganising and reconstructing concepts they learn in different disciplines. Encouraging learners to connect disciplinary knowledge with everyday ideas and ways of thinking, though central to the current curriculum, appears to be less appealing to teachers because it contradicts their beliefs.

Pedagogic incongruity

Considering the nature of beliefs about teaching and learning, it appears that teachers are likely to narrowly conceive or resist learner-centred pedagogy because their beliefs contradicts with the principles and practice of learner-centred pedagogy in fundamental ways, which I discuss next.

First, while the curriculum emphasises teaching science as a way of knowing by actively engaging students in collaborative inquiry, teachers are preoccupied with delivering textbook content (Bernstein, 2000). They believe that dictating content for students to memorise instead of creating a space for active interaction, inquiry and critical thinking could optimise learning. Teachers espoused such beliefs when they described teaching science as giving students the knowledge they need to pass public examinations. The impact of this vision of good teaching, which contrasts with the reform ideals, is a widespread transmissive teaching style in which teachers convey knowledge and ask factual questions to prompt choral responses. Such teaching reinforces a view of learning as the acquisition of textbook content, which in turn cultivates a conception of knowledge as uncontested objective truths.

Second, although the curriculum emphasises meaningful learning through active engagement of students by reflecting on and making connections between subject concepts, the teachers advocated the impersonal acquisition of inert content. They narrowed learning to the simple accumulation of knowledge and passing exams, contrary to the reform goals of promoting understanding and conceptual growth. The idea of 'giving students what they are supposed to know', which featured in teachers' descriptions of good science teaching, is clearly inconsistent with a learner-centred approach in which the emphasis is on empowering students to construct knowledge. Considering their views, teachers seem less likely to encourage students to ask scientific questions relating to their own interests, collect evidence, and build their own conclusions about natural phenomena. For them, the essence of teaching is to encourage learners to accrue the textbook knowledge they need to pass public exams, instead of the personal development of learners as envisioned in the curriculum.

The curriculum itself lacks propensity for learner-centred teaching and learning because it places contradictory demands on teachers (Sabella and Crossouard, 2017). On the one hand, it requires teachers to promote deeper learning through active pedagogy; on the other hand, there exists a well-established accountability system in which teaching and learning effectiveness is judged according to examination results. The exam itself is high stakes and measures students' recall of textbook facts (Semali and Mehta, 2012; Vavrus and Bartlett, 2012).

Because teaching focused on promoting meaningful and holistic understanding does not often immediately translate into good exam grades, teachers are compelled to transmit tested facts for students to memorise and use to pass exams. This means that the accountability system contradicts the very aim of promoting active pedagogy that the curriculum claims to promote. By underscoring the importance of grades, the accountability system motivates teachers' preference for transmissive teaching strategies that they have found to be effective at helping students to pass exams. The curriculum defines what counts as valid knowledge and pedagogic modes, while the accountability system defines what counts as valid achievements (Bernstein, 2000). In short, the accountability system militates against a learner-centred pedagogy and sustain transmissive teaching.

Further, the curriculum is strongly framed by specifying the content, pace, and time at which teachers should teach (Bernstein, 2000). The syllabi specify lesson duration, activities, and task that teachers and students should accomplish in the allotted time. Teachers, and rarely students, control how such specifics are enacted during the actual lessons, thereby cultivating a hierarchical teacher–student relationship. Such power privileges translation into pedagogical practices in which the teacher controls the teaching and learning process, leaving students with no space to participate (Sabella and Crossouard, 2017). Therefore, the framing of the curriculum is paradoxical because it prescribes a rigid teaching organisation and claims to promote a learner-centred pedagogy in which flexible teaching shaped by learners' needs and prior dispositions are central. If learners should assume responsibility for their own learning, then their voice, needs, interests and experiences should be considered in the teaching organisation.

Lastly, even the few teachers who espoused teaching that creates a space for students to participate in learning activities, during actual teaching were preoccupied with prioritising content delivery over student activities. In addition, they described student activities as means to help them memorise textbook content. Indeed, these teachers could not enact practices that reflect their constructivist beliefs about teaching and learning.

Overall, the beliefs about science knowledge, teaching and learning that teachers espoused are largely antithetical to the principles of a learner-centred pedagogy upon which the current secondary school curriculum in Tanzania is founded. This may be partly preventing teachers from fully adopting a learner-centred pedagogy in their actual classroom practices. However, teachers' espousals of beliefs that are aligned with the principles of a learner-centred pedagogy were not sufficient for them to enact such principles in practice. The schools' social and contextual conditions should be supportive for teachers to adopt the reforms. Nonetheless, it appears that the principles of the learner-centred pedagogy espoused in the curriculum are idealistic because the powerful drivers of teaching change including exams remain unaltered. Such school structures work against the very principles that the curriculum is supposed to promote. In what follows, I discuss how school social and contextual conditions contribute to sustaining the traditional teacher-centred pedagogy in Tanzania.

8.3.2 Mediating role of school structures

In chapter 6, I identified social and contextual conditions shaping and forming teachers' beliefs. I showed how these closely cohere with teachers' beliefs. Most importantly, I described how these social and contextual variables influence how teachers enact their beliefs in practice, thereby shaping actual teaching. I argue that this partly contributes to the resilience of teacher-centred transmissive teaching and recitation learning, thereby militating against the envisaged learner-centred pedagogy. In this section, I demonstrate this argument by discussing how teachers actively attempt to align their actual teaching practices with bureaucratic demands, school norms and their own schooling experiences.

Teachers consciously and unconsciously modelled the practices of their own former teachers whom they admired for their proven mastery and delivery of knowledge. They adopted lecturing styles and the dictation of notes for students to copy, much of which symbolised the transmissive teaching I observed during their lessons. In short, teachers espoused and practised teaching that was consistent with their own schooling experiences.

Teachers also sought to teach following the expectations of parents, students and school principals, despite those expectations conflicting with the envisaged learner-centred pedagogy. Efforts to align teaching with school norms were demonstrated by devoting significant parts of the lesson to helping students practise solving typical exam items and learning techniques for tackling exam questions. Teachers testified that 'they taught students how to solve exam questions and share their experiences on the expected pattern of answers in the national examinations'. They did this to fulfil parents' and students' ideas of successful learning as passing examinations.

Equally, bureaucratic demands requiring teachers to cover the mandated syllabus and help students to pass exams have influenced the teachers' pedagogical choices and decisions. The fact that school principals reward and sanction teachers for their students' exam results obliges teachers to prioritise equipping students with textbook knowledge and assessing students' ability to recall (Vavrus and Bartlett, 2013). Teachers found such accountability requirements best achievable through transmissive teaching, drilling, recitation, practising with past exam items and test-taking skills (Hardman, 2015). Such strategies, though effective at promoting rote learning and passing examinations, are in contrast with the curriculum requirement of promoting critical thinking and deeper learning through learner-centred pedagogy.

Under such circumstances, where the curriculum policy emphasises deeper learning through active pedagogy, yet powerful accountability structures such as examinations focus on testing students' ability to recall facts, it is difficult for teachers to prioritise a pedagogy that promotes active and meaningful knowledge construction. Indeed, the teachers found it difficult to choose between promoting content acquisition to pass exams and promoting meaningful learning through activities. The breadth of the exams, which encapsulates four years of content for a minimum of seven subjects, means that it is unrealistic for students to learn both the content knowledge and higher-order thinking skills (Vavrus and Bartlett, 2013). Overall, school structures influence the type of beliefs that teachers enact when they hold more than one set of contradictory beliefs. Often, such structures support or reward beliefs that translate into teacher-centred teaching.

8.4 Conclusion

A significant insight from this study is that, although teachers may be introduced to innovative ideas about science, teaching and learning, their ability to translate them into practice is not only dependent on whether they espouse such ideas but also on how educational structures including curricula, exams and textbooks support the reform proposals. Teachers may hold different beliefs about science knowledge, teaching and learning, but their predominant adherence to a teacher-centred pedagogy is a reflection that their 'core' beliefs, which are ingrained in their own schooling and first-hand experiences of learning and teaching, reinforced by the educational structures. Initiatives to change teachers' pedagogical practices must therefore focus on teachers' beliefs and the current system-wide structures that strongly support a teacher-centred pedagogy. This points to teacher education through raising awareness of these issues and working with student teachers to explore opportunities within the education system that can provide a space for new ideas to develop and grow, as further explained next.

8.5 Recommendations

Considering the nature of science teachers' beliefs, and how these manifested in their actual teaching practices, initiatives to transform teachers' beliefs are imperative. In theory, for teaching reforms to succeed, teachers should believe in the fundamental principles underlying the envisioned change (Fives and Buehl, 2016; Levitt, 2002; Yerrick et al., 1998). Since science teachers in this study espoused beliefs that contrasted with the basic principles of learner-centred pedagogy, there is a need to inculcate in teachers the core beliefs aligned with the advocated pedagogical practices beyond introducing teachers with the innovative ideas. Alternatively, for teachers to change their practices, they need to change their beliefs to align with the reform proposals (Markic and Eilks, 2013). Giving teachers and student teachers the opportunities to reflect, articulate and interrogate their beliefs can trigger belief change (Hofer and Pintrich, 1997). This will create a perceived need for change or dissatisfaction with their old beliefs, which should be followed by giving sound alternatives upon which teachers can draw to improve their practices (Bryan, 2012; Hofer and Pintrich, 1997).

In Tanzania, teacher education and professional development programmes equipped with learning trajectories that offer opportunities for teachers to identify, reflect on, challenge and transform their beliefs are necessary. Such trajectories should offer alternative beliefs drawn from the assumptions and principles of the desired learner-centred pedagogy. In other words, the ‘right’ discourses about teaching, learning and the nature of science knowledge needs emphasis in the context of teacher education and professional development. For example, opportunities for student teachers to reflect on how scientific knowledge is created, reviewed, and improved should be explored to help teachers develop a more sophisticated understanding of science.

Furthermore, changing teachers’ well-established beliefs remains complex unless attempts to transform beliefs are connected with the socio-cultural and structural context in which teachers teach (Brownlee et al., 2001; Kang and Wallace, 2005; Markic and Eilks, 2013). In section 8.2, I demonstrated how school structures influenced the type of beliefs that teachers prioritise and enact in practice. This means that helping teachers acquire beliefs supportive a learner-centred pedagogy is not sufficient unless such attempts take into account the social and structural constraints in schools. In Tanzania, education structures including high-stake exams, curricula, textbooks, and teacher accountability system will continue to influence the type of beliefs teachers enact, even if they acquire beliefs supportive of learner-centred pedagogy. Therefore, attempts to deconstruct and reconstruct teachers’ beliefs should take place in relation to the structural forces that inevitably shape teaching. Through school-based mentoring - via cycles of teaching, reflections and analysis - teachers should be supported to concomitantly promote deeper learning through active pedagogy in the context of high-stake exams and resource-constrained classrooms.

To enact the recommendations discussed above needs a collaboration of various stakeholders within the current education system in Tanzania. Considering their role in implementing teacher education policies and preparing teachers, teacher educators are the key change agents. To what extent they can play this primary role and the obstacles they are likely to encounter in the current educational structures depends on the level of teacher education.

For teacher educators engaged in preparing diploma level teachers, the teacher education curriculum is 'prescriptive'. It is designed by the Tanzania Institute of Education and examined by the National Examination Council of Tanzania. Therefore, what teacher educators at this level can achieve in terms of transforming teachers' deep-seated beliefs is constrained by the rigid top down teacher education curriculum. In this context, teacher educators need to collaborate with the TIE, which should incorporate into initial teacher education curriculum the learning trajectories that requires teacher educators to explore, challenge and transform the deep-seated beliefs that teacher candidates bring when they join teacher education at diploma level.

However, teacher educators at diploma level are the graduates of the same system of education that reinforced beliefs that appears to impede the adoption of learner-centred pedagogy. Teacher educators' own beliefs could constrain them from acting as agents of change. To transform such beliefs, a professional development requiring teacher educators to interrogate their own beliefs is necessary. This can be organised by the teacher education department in the Ministry of Education in collaboration with the colleges of teacher education. When provided with the required curriculum and professional development that offers them opportunity to reflect and deconstruct their own beliefs and practices, teacher educators at diploma level are better positioned to serve as change agents.

University-based teacher educators are better positioned to implement change initiative because the universities are semi-autonomous organisations entitled to design, review and implement their teacher education programs. Although such programs require approval by the University Senate and the Tanzania Commission for Universities, the structures are less prescriptive compared to diploma level. My positionality as an instructor for science method courses at the University can illustrate personal and institutional initiatives that can be implemented.

Personally, I can review the course structure in order to incorporate learning opportunities that engage student teachers to reflect and interrogate their beliefs. I can modify course delivery by challenging student teachers' beliefs early at the beginning of their training and modelling effective practice through my own teaching. At the institutional level, opportunities to share and disseminate the results of this research to wider faculty as part of the research and professional development can be utilised. The impact of knowledge sharing and awareness rising initiatives can however be constrained by hierarchical rather than collegial relationship among faculty members. Most importantly, teacher educators' own beliefs and background experiences are likely to influence their commitment to utilise the knowledge they acquire. As discussed in chapter six, teacher educators' classroom practices reflect much of what is happening in secondary schools. Therefore, despite institutional flexibilities for change initiatives, teacher educators' profiles may narrow what can be achieved considering that they were ideally trained as secondary school teachers.

Finally, the broader socio-cultural norms of Tanzanian society are likely to remain countervailing to some of the principles and practices of a learner-centred pedagogy. Science teacher educators may confront teachers with sophisticated views of knowledge as being tentative, integrated, and uncertain, and that generating it inevitably includes scientists' personal beliefs and imaginations, yet the broader epistemology of the society remains contradictory. This raises a question about the relevance of learner-centred education reforms for a country that is dominated by cultures in which high-status knowledge is attributed to deities and elders. The assumptions about legitimate knowledge, how it comes into existence and how it can be known that underlie the epistemology of Tanzanian society appear to be incompatible with the desired constructivist-based learner-centred pedagogy. Whether such incongruences are reconcilable is a question that policy makers and researchers need to address.

Attempts to reconcile the discontinuities between socio-cultural values and innovative practices such as learner-centred pedagogy may point in multiple directions. This may involve exploring the interconnections between culture and innovative pedagogies by identifying and recognising elements within the indigenous modes of knowing and teaching that can support innovation. Afterwards, pedagogical innovations can be built on the foundations of supportive cultural elements and the desired outcomes of successful schooling including attainment of higher order skills be pursued. In short, pedagogical innovation should be implanted into culture instead of implanting culture into the pedagogical innovation. Moreover, successful pedagogical innovation can also be redefined considering the existing cultural context instead of prescriptive universal solution to the problem of ineffective teaching.

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Appendices

Appendix I: Science Teacher Interview Protocol

School	Subject	Gender	Experience	Qualification

INTERVIEW 1

1. How did you develop interest in science and science teaching?
   - How do you compare your interest in science and other subjects?
   - How would you describe your learning achievement in secondary school science?
2. How would you describe your past experiences of school science learning?
   - How did you learn science? What were your learning strategies? What roles did you play as learner? Did you consider yourself a successful school science learner? Why?
   - Did you like any of your school science teachers? Why?
   - How would you describe their teaching? Why were you impressed?
   - Did any of your school science teachers influence your decision to become science teacher? How?
   - Do you teach like any of your school science teachers? In what ways, do you think your science lessons resemble or differ from those of your school science teachers? Did any of these teachers become your role model for science teaching? Why?
   - Did you dislike any of your school science teachers? Why?

INTERVIEW 2

1. How would you describe your science learning experiences at the college or university? How did you learn science?
2. What practices did you learn from your college instructors?
3. How did this influence your science teaching practices?
4. Did any of the college instructors become your role model for teaching science? Why?
5. Did the teaching practices of any of your college instructors impress you? Have you adopted any of these practices? How would describe these practices?
6. Did you dislike any practices of your college instructors? What are they? Why?

INTERVIEW 3

1. What do others (learners, teachers, and administrators) consider to be your role as a science teacher? How do these expectations influence your teaching practices?
2. In your view, what do science learners consider to be your role as a teacher in a typical science lesson? How do these expectations influence your teaching practices?
3. What do learners consider to be the purpose of learning science?
   - What do they consider to be success in science learning?
   - What do they do to achieve success in science learning?

4. In your view, what do school administrators consider as successful science learning?
5. In your view, what do parents consider as successful science learning?

6. How do these expectations influence your teaching practices?

INTERVIEW 4

1. If science knowledge in books differs or contradicts what you know from experience which one would trust most? Why?
2. Do you think science knowledge written by experts in books is correct? Do you question it? Why?
3. If one science textbook contradicts with another textbook on the same concept, what will you do? Which one will you trust most? Why?
4. Do you think most science questions teachers ask students in the classrooms have one correct answer? Why?
5. How do you know that the science knowledge your teaching is true?
6. Suppose your student disagree or question the accuracy of the procedure or solution to a problem you presented, how do you justify your position?
7. Do you think science knowledge changes? Or is it something that does not change? Why do you think so?
8. How would you view a student who uses knowledge from other subjects to answer questions on the subject your teaching?

INTERVIEW 5

1. Do you remember any successful science lesson you have taught recently?
    - How was it like? How did you teach it? What students did? What methods did you use? Why?
    - Why do you think it was successful?
    - What roles did you play in this lesson? Why do you think it was important for you to do that?
2. How would you describe good science teaching? /what are the characteristics of good science teaching?
    - What methods and strategies do you believe to be most effective for science teaching? Why?
    - How are these approaches similar to those recommended in the syllabus?
    - How would you describe the role of teacher during the science teaching and learning process?
    - How would you describe role of learners in science learning process?
    - What would you consider to be the outcome of a good science teaching for students?

3. How would you describe your preferred teaching approaches?
    - How are these approaches like those recommended in the curriculum?
    - In your typical lesson, how do you engage students in teaching and learning process?
    - How would you describe your roles during the teaching and learning process?
    - In what ways does prior students' learning inform your teaching?
    - In your view, what should the teacher do if student's prior understanding is not in agreement with the concept being taught?

INTERVIEW 6

1. Why is it important for students to learn science?
    - What goals do you aspire your students to achieve in science?
    - What does learning science means for your students?
    - What evidence would you consider as learning?
    - How do you feel when your students can not remember what you taught?
    - How do you feel when your student can not get examination question correct?
2. How would you describe your successful science learner(s)?
    - What initiatives do students take to achieve learning success in your class?
    - What initiatives do you take to ensure your learners succeed?
    - Do you modify your teaching practices to ensure learners achieve their learning success? How?
3. Why do you think some learners learn quickly while others take long time?
   Do you think learners who learn slowly can learn to learn quickly? Why?
4. Why do you think some concepts are learned quickly while others take long time?

Appendix II: Classroom Observation Protocol

Date	School	Subject	Class	Time	Students	topic

	Elements of the lesson observed	Notes
1	**Physical organization of the classroom**	
	How were the desks, chairs, and chalkboard arranged? How does this influence interaction? Where is the focal point for students' attention? How did the teacher position himself/herself in relation to students? How students position themselves in relation to teacher and to each other? How does this influence interaction? What movements are made in relation to learning activities? How is organization altered to suit learning activities e.g. pull chairs close to discuss?	
2	**Organization of time**	
	At the school level: How is time organized**?** It is concentrated or dispersed, flexible or rigidly framed? **At classroom level**: Are lessons regular or irregular?	
3	**Setting learning intentions**	
	Does the teacher state learning objectives? How explicit were they for students? How were the students engaged in setting direction and focus of the lesson? Did students seem to understand why they were doing learning activities?	
4	**Exploring students' prior understandings**	
	How does the teacher elicit prior students' understandings? How does the teacher connect new concepts to pre-existing students understanding of concepts? How did students connect new concepts with what they already know?	
5	**Nature of learning Task**	
	Does the teacher present single task or series of tasks? Does the task focus on acquisition of knowledge or transformation of knowledge? Is the task tightly framed, specified or open-ended? E.g. is the teacher seeking single right answers or divergent answers?	

	Does the task require students to receive, accept and use knowledge in the form it is presented or translate it into something else? Was the task challenging? E.g. were the students asked to provide evidence for their reasoning, back up their claims or critique others' claims? Does science knowledge seem to be dynamic, changing with teachers and students' experiences? Does learning seem to be the process of inquiry and construction?	
6	**Nature of teaching and learning activities**	
	What teaching strategies were used? How does the strategy actively engage students in learning? What learning activities did students perform? How were the activities performed? E.g. individually, in groups, plenary Does the teacher encourage creativity and divergence of opinion? E.g. Was single right answer sought?	
7	**Classroom interaction**	
	Who does most talk? Teacher or students? What role does the teacher play? Explaining? Facilitating? Guiding activities? What roles do students play? Mostly listening? Planning and conducting investigations? Did students interact with teacher e.g. whole class dialogue? Did students interact among themselves e.g. small group dialogue/activities?	
8	**Classroom management**	
	Does teacher face any discipline problems e.g. off-task, noisy students? What strategy was used to solve discipline problems?	
9	**Classroom assessment**	
	Does teacher ask open-ended thought provoking questions? Note examples Does teacher ask close-ended questions? Does the teacher allow adequate wait time e.g. 5 seconds? Was single answer to question acceptable? Or divergent alternative answers sought? What assessment methods were used? Did the teacher provide feedback? How was the feedback used by students?	

10	**Classroom culture**	
	Did students seem confident to ask questions, clarification, critique claims by teacher, colleague, or book? How did the teacher motivate students learning? E.g. Using due dates, preparation for exams, minimum achievement requirements, encouraging competition on tests, addressing students' interests? Does this seem threatening or motivating?	

Appendix III: Ethical approval certificate

University of Sussex

Certificate of Approval	
Reference Number:	ER/AT401/1
Title Of Project:	Exploring science teachers' conceptions of science knowledge, teaching and learning and their teaching practices in Tanzanian secondary schools
Principal Investigator (PI):	Albert Tarmo
Student:	Albert Tarmo
Collaborators:	
Duration Of Approval:	n/a
Expected Start Date:	01-Jun-2015
Date Of Approval:	11-Jul-2015
Approval Expiry Date:	30-Sep-2018
Approved By:	[redacted]
Name of Authorised Signatory:	
Date:	11-Jul-2015

*NB. If the actual project start date is delayed beyond 12 months of the expected start date, this Certificate of Approval will lapse and the project will need to be reviewed again to take account of changed circumstances such as legislation, sponsor requirements and University procedures.

Please note and follow the requirements for approved submissions:

Amendments to protocol

* Any changes or amendments to approved protocols must be submitted to the C-REC for authorisation prior to implementation.

Feedback regarding the status and conduct of approved projects

* Any incidents with ethical implications that occur during the implementation of the project must be reported immediately to the Chair of the C-REC.

Feedback regarding any adverse and unexpected events

* Any adverse (undesirable and unintended) and unexpected events that occur
during the implementation of the project must be reported to the Chair of the Social Sciences C-REC. In the event of a serious adverse event, research must be stopped immediately and the Chair alerted within 24 hours of the occurrence.

Appendix IV: Research clearance

UNIVERSITY OF DAR-ES-SALAAM
OFFICE OF THE VICE CHANCELLOR
P.O. BOX 35091 ♦ DAR ES SALAAM ♦ TANZANIA

General: +255 22 2410500-8 ext. 2001
Direct: +255 22 2410700
Telefax: +255 22 2410078

Telegraphic Address: UNIVERSITY OF DAR ES SALAAM
E-mail: vc@admin.udsm.ac.tz
Website address: www.udsm.ac.tz

Ref. No: AB3/12(B)

Date: 22nd July, 2015

Regional Administrative Secretary
Dar es Salaam

RE: REQUEST FOR RESEARCH CLEARANCE

The purpose of this letter is to introduce to you **Mr. Albert Paulo Tarmo** who is a bonafide staff of the University of Dar es Salaam who is currently pursuing doctoral studies at University of Sussex in the UK and who is at the moment required to conduct research. Our staff members undertake research activities as part of their studies and core functions.

In accordance with government circular letter Ref. No. MPEC/R/10/1 dated 4th July 1980, the Vice-Chancellor of the University of Dar es Salaam is empowered to issue research clearances to staff members and students of the University of Dar es Salaam on behalf of the government and the Tanzania Commission for Science and Technology (COSTECH). I am pleased to inform you that I have granted research clearance to Mr. Tarmo.

I therefore request you to grant him any help that may enable him achieve his research objectives. Specifically we request your permission for him to meet and talk to the leaders and other relevant stakeholders in your region in connection with his research.

The title of his research is **"Exploring Science Teachers' Conceptions of Science Knowledge, Teaching and Learning and their Teaching Practices in Tanzanian Secondary Schools".**

The period of his research is from **August 2015 to January 2016** and the research will cover the **Dar es Salaam Region.**

Should there be any restriction, you are kindly requested to advise us accordingly. In case you may require further information, please do not hesitate to contact us through the Directorate of Research, Tel. 2410500-8 Ext. 2084 or 2410727 and E-mail: research@udsm.ac.tz.

Yours sincerely,

VICE CHANCELLOR
UNIVERSITY OF DAR-ES-SALAAM
P.O. Box 35091
DAR-ES-SALAAM

Prof. [redacted]
VICE-CHANCELLOR

QUOTATION OF REF NO IS ESSENTIAL

Appendix V: Research Permit-Regional

The United Republic of Tanzania
PRIME MINISTER'S OFFICE
REGIONAL ADMINISTRATION AND LOCAL GOVERNMENT

DAR ES SALAAM REGION

Phone Number: 2203156/2203158
In reply please quote:

Ref. No. ....

REGIONAL COMMISSIONER'S OFFICE,
P.O. Box. 5429,
DAR ES SALAAM

Date: 03/08/2015

District Administrative Secretary,
KINONDONI
DAR ES SALAAM

RE: RESEARCH PERMIT

Prof/~~Dr~~/~~Mr.~~/~~Mrs~~/Ms/Miss. ALBERT PAULO TARMO is student/researcher from UNIVERSITY OF DAR ES SALAAM has been permitted to undertake a field research on Exploring Science teachers' Conceptions of Science knowledge, Teaching and Learning and their practices in Tanzanian Secondary Schools

From August 2015 to January 2016

I kindly request your assistance to enable him/her to complete his/her research.

For: Regional Administrative Secretary
DAR ES SALAAM

Copy to: Municipal Director,
KINONDONI
DAR ES SALAAM

" Principal/Vice Chansellor.

Appendix VI: Research Permit-District

THE UNITED REPUBLIC OF TANZANIA
PRIME MINISTER'S OFFICE
MINISTRY OF REGIONAL ADMINISTRATION AND LOCAL GOVERNMENT

KINONDONI DISTRICT

Telephone No. 2170169 / 2170183

To reply please quote:

Ref. No. AB.320/378/01/128

THE DISTRICT COMMISSIONER'S OFFICE,
P.O BOX 9583,
KINONDONI,
DAR ES SALAAM,
TANZANIA.

4th August, 2015

....,
....,
....

RE: RESEARCH PERMIT

Albert Paulo Tarmo is a student from University of Dar es Salaam. He has been permitted to undertake field work research on **"Exploring Science Teachers Conceptions of Science Knowledge, Teaching and Learning and their Practices in Tanzania Secondary Schools."** from August, 2015 to January 2016.

I kindly request your good assistance to enable him to complete his research.

[redacted]

For:-District Administrative Secretary
KINONDONI

Appendix VII: Consent Form I

Lesson Observation Consent Forms for Science Teachers

Research title: Exploring science teachers' conceptions of science knowledge, teaching and learning and their teaching practices in Tanzanian secondary schools

I allow Albert Tarmo who is a Doctoral researcher to observe my teaching practices during my science lessons. I understand that:

- My decision to allow the researcher to observe my teaching practices is voluntary and I may decide not to be observed at any time without giving reasons for my decision. However, I realise that the withdrawal of my data will not be possible once the analysis begin in 1st March 2016.
- The researcher will observe and take notes on my teaching practices and ask for clarification on the same
- Observation notes and the clarifications I provide on my teaching practices will be used by the researcher in writing his PhD thesis, journal articles and conference presentations.
- The researcher will keep the information gathered in securely locked cupboards to ensure that it remain confidential.
- My name, the name of the school where I teach, and any other identifying details will be changed and will not be revealed or used in the publication.

Thank you very much for volunteering to be interviewed, please fill the information required in the space provided below.

Name: [redacted]

Signature: [redacted] Date: 20/9/2015

Contact researcher:	Contact Supervisor
Albert Paulo Tarmo	Professor Kwame Akyeampong
University of Sussex	University of Sussex
Department of Education	Department of Education
Essex House 135	Essex House 144
Brighton, UK	Brighton, UK

Appendix VIII: Consent form II

Interview Consent Forms for Science Teachers

Research title: Exploring science teachers' conceptions of science knowledge, teaching and learning and their teaching practices in Tanzanian secondary schools

I have allowed Albert Tarmo who is a doctoral researcher to interview me. I understand that:

- My decision to be interviewed is voluntary and I may decide not to be interviewed or not to answer any questions, at any time without giving reasons for my decision.
- I realize that the withdrawal of the information I provide will not be possible once thesis writing begin on the 1st march 2016.
- During the interview the researcher will ask me questions and my responses will be audio recorded.
- Audio recorded interview responses will be transcribed. The transcripts will be analysed and used by the researcher in writing his PhD thesis, journal articles and conference presentations.
- Files containing information I provide will be password protected (encrypted) and locked in the secured cupboards to ensure security and confidentiality of information. These will be accessible only to the researcher.
- My name, the name of the school where I teach, and any other identifying details will be changed, will not be revealed or used in the publication.
- I may be provided with the summary of the results if I wish.

Thank you very much for volunteering to be interviewed, please fill the information required in the space provided below.

Name: [redacted]

Signature: [redacted] Date: 27/08/2015

Contact researcher:	Contact Supervisor
Albert Paulo Tarmo	Professor Kwame Akyeampong
University of Sussex	University of Sussex
Department of Education	Department of Education
Essex House 135	Essex House 144
Brighton, UK	Brighton, UK
BN1 9QQ	BN1 9QQ
paulo.albert@yahoo.com/at401@sussex.ac.uk	A.Akyeampong@sussex.ac.uk

Appendix IX: Information Sheet I

Interview Information Sheets for Science Teachers

Research title: Exploring science teachers' conceptions of science knowledge, teaching and learning and their teaching practices in Tanzanian secondary schools

Dear science teacher!
My name is Albert Paulo Tarmo, I am a PhD student at the University of Sussex, Centre for International Education. I have been teaching science in secondary schools in Tanzania. I am currently doing my field work which involves talking to science teachers and observing their teaching practices as part of my PhD study.

Description of Research
This study is exploring science teachers' conception of science knowledge, teaching and learning and its relation to their teaching practices in secondary schools in Tanzania. The aim is to understand how science teachers' conceptions of science knowledge, teaching and learning mediate their teaching practices.

How will you be involved?
I would like to talk to you about your conception of science knowledge, teaching and learning and what has shaped your conceptions of these aspects of your professional role in an interview that may take place between 1st June 2015 and 1st March 2016. Interview will take up to 90 minutes and will be audio recorded. I and you will agree on the setting where the interview will be conducted. You are also invited to a follow-up interview where I will give you the summary of the interview for you to check and give feedback. You will have right to delete, alter, or add any information during the follow-up interview.

What will I do with the information?
I will transcribe interview recordings and store them in a password protected or encrypted digital folders. These folders will be stored in hard drives which will be kept in securely locked cupboards accessible to the researcher only. I will analyse and use the transcripts in writing my PhD thesis which will be accessible through the University of Sussex library. I may also use the transcripts in writing journal articles and conference presentations. I will send to you, a summary of the results if you wish.

Will my personal information be kept confidential?
Your name and the name of your school will be changed so that your identity will not be revealed. Audio records of interviews will be password protected or encrypted and

stored in securely locked cupboards. These will be destroyed after writing my PhD thesis.

Participating and withdrawing

I will interview you only if you volunteer to be interviewed. You can decide not to be interviewed or not to respond to any questions at any time without giving reasons for your decision. In case you decide not to be interviewed or your responses not to be used, let me know, so that I can ensure that information you provided is not included in the final report. I will be able to conveniently remove your information from the final report between 1st June 2015 when the study commence and 1st March 2016 when I will start writing final report.

Contact Person

If you have any question regarding this study at any stage please contact me or my supervisor Professor Kwame Akyeampong using the contacts provided below:

Contact researcher:	**Contact Supervisor**
Albert Paulo Tarmo	Professor Kwame Akyeampong
University of Sussex	University of Sussex
Department of Education	Department of Education
Essex House 135	Essex House 144
Brighton, UK	Brighton, UK
BN1 9QQ	BN1 9QQ
paulo.albert@yahoo.com/at401@sussex.ac.uk	A.Akyeampong@sussex.ac.uk

Appendix X: Information Sheet II

Lesson Observation Information Sheet for Science Teachers

Research title: Exploring science teachers' conceptions of science knowledge, teaching and learning and their teaching practices in Tanzanian secondary schools

Dear science teacher!

My name is Albert Paulo Tarmo, I am a PhD student at the University of Sussex, Centre for International Education (CIE). I have been teaching science in secondary schools in Tanzania. I am currently doing my field work which involves talking to science teachers and observing their teaching practices as part of my PhD study.

Description of Research

This study is exploring science teachers' conception of science knowledge, teaching and learning and its relation to their teaching practices in secondary schools in Tanzania. The aim is to understand how science teachers' conceptions of science knowledge, teaching and learning mediate their teaching practices.

What and Who am I Observing?

I will be observing your science teaching practices during your lessons. In particular, I am interested to see how your classroom is physically organized, how you interact with students, teaching strategies you are using and the kind of learning tasks and activities you assign to your students. This may be followed by short conversation about your practices after the lesson. The study does not directly focus on students though they will be part of your class automatically. In any case whenever I am referring to students I will identify them as student(s). No personal information about students will be recorded.

When and how will I Observe?

I will accompany you during your lesson; sit at the back of classroom to observe your teaching practices and take notes on your teaching practices. I may also talk to you about the practices I observed just after the lesson.

What will I do with the information?

I will compile and analyze observation notes, then use it to answer my research questions as part of my PhD thesis which will be accessible through University of Sussex library. I will send to you, summary of the results if you wish. Observation notes may also be used in writing journal articles and conference presentations.

Will my personal information be kept confidential?

Your name and the name of your school will be changed so that your identity will not be revealed. Copies of observation notes I take during lesson observation will be stored in securely locked cupboards accessible to the researcher only, these will be destroyed at the end of my PhD study.

Participating and withdrawing

I will observe your lessons only if you volunteer to be observed. You can decide not to be observed at any time without providing reasons for your decision. So let me know in case you have decided not to be observed and I will ensure that I will not include any information about you or your practices in the final report. I will be able to conveniently remove your information from the final report between 1st June 2015 when the study commence and 1st march 2016 when I will start writing final report.

Contact Person

If you have any question regarding this study at any stage please contact me or my supervisor Professor Kwame Akyeampong using the contacts provided below:

Contact researcher:	**Contact Supervisor**
Albert Paulo Tarmo	Professor Kwame Akyeampong
University of Sussex	University of Sussex
Department of Education	Department of Education
Essex House 135	Essex House 144
Brighton, UK	Brighton, UK
BN1 9QQ	BN1 9QQ
paulo.albert@yahoo.com/at401@sussex.ac.uk	A.Akyeampong@sussex.ac.uk